PE&RS

April 2024 Volume 90, Number 4

PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING *The official journal for imaging and geospatial information science and technology*

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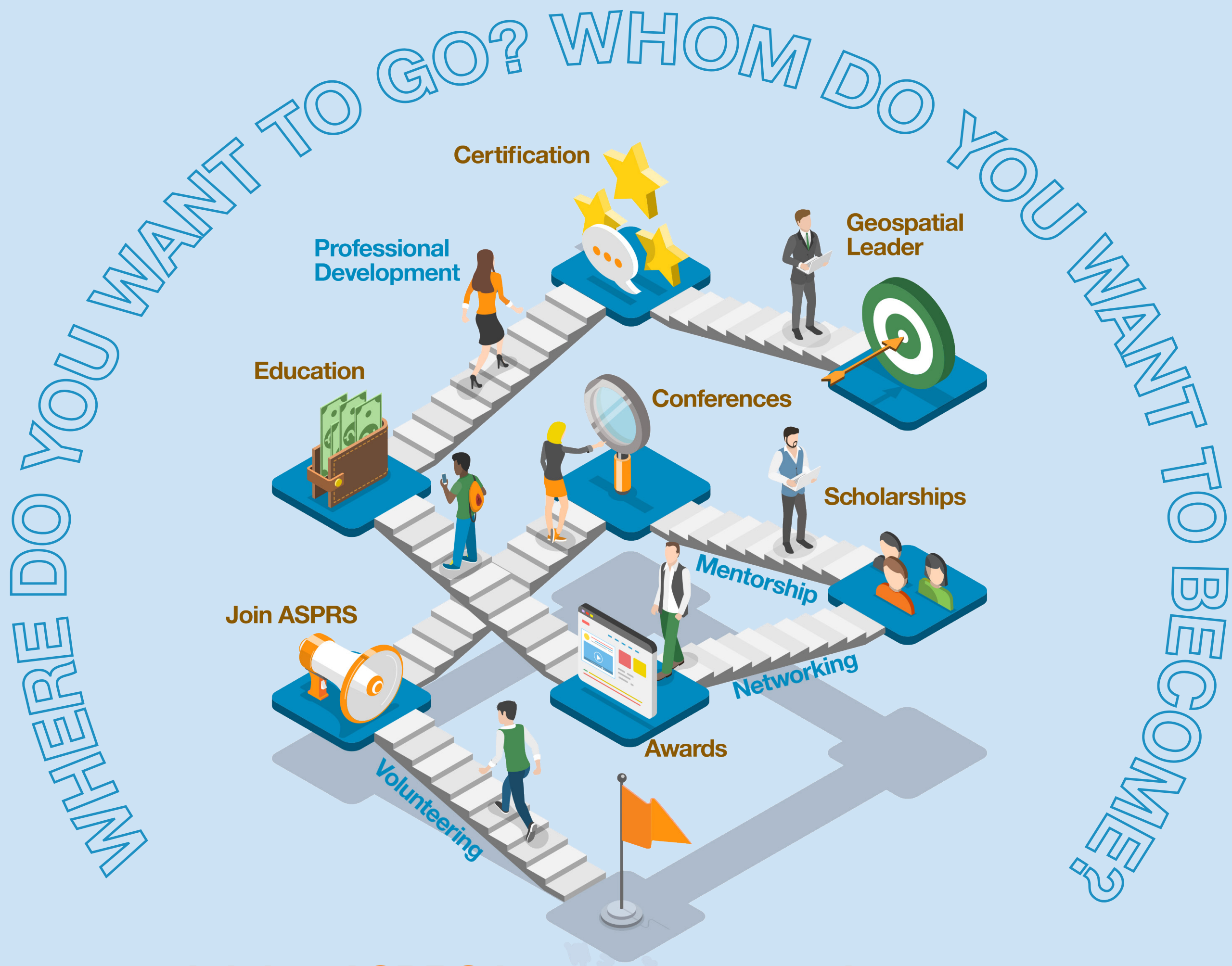

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To have your press release published in *PE&RS*, contact Rae Kelley, rkelley@asprs.org.

ANNOUNCEMENTS

The **2024 William T. Pecora Awards Nominations** Now Being Accepted through MAY 15, 2024 -- The William T. Pecora Award is presented annually to individuals or groups who have made outstanding contributions toward understanding the Earth by means of remote sensing. The Department of the Interior (DOI) and the National Aeronautics and Space Administration (NASA) jointly sponsor the award.

The award was established in 1974 to honor the memory of Dr. William T. Pecora, former Director of the U.S. Geological Survey and Under Secretary, Department of the Interior. Dr. Pecora was a motivating force behind the establishment of a program for civil remote sensing of the Earth from space. His early vision and support helped establish what we know today as the Landsat satellite program.

The Award Committee must receive nominations for the 2024 award by May 15, 2024.

Additional information on eligibility and nominations can be found at https://www.usgs.gov/programs/national-land-imaging-program/william-t-pecora-awards or on the attached flyer; and questions can be directed to the Executive Secretary and Committee at pecora@usgs.gov.

SAM, www.sam.biz, is pleased to announce our partnership with the City of Hutto, TX, to provide Geomatics services for their Survey and Land Services Rotation List. This is an exciting opportunity to work hand-in-hand with a neighboring town in the Austin-Round Rock Metroplex, just a few miles away from SAM's original headquarters.

This contract will entail a wide variety of tasks that will benefit from SAM's full suite of services, including ALTA surveys, topographic surveys, metes and bounds descriptions, Aerial Mapping, and Subsurface Utility Engineering (SUE) services. The purpose of these is broad and will enable improvements to the city's transportation, utilities, and drainage infrastructure.

SAM was selected for this task due to our comprehensive Managed Geospatial Services™ framework, allowing for the seamless integration of all facets of the Geospatial services we will deliver to the city. Moreover, as one of the most geographically diverse states in the country, operating across all six of Texas' regions requires SAM to have broad capabilities—and extensive industry experience. We are fully equipped to provide those services both statewide and nationally, including SUE Mobile and Aerial Lidar, and usage of both crewed and uncrewed aircraft to aid in spatial data collection.

No one knows the Lone Star State better than SAM. Learn more about the full suite of Geomatics services and how we can help conquer even the most Texas-sized projects.

Greenville Water has contracted **Woolpert**, woolpert.com, to acquire bathymetric survey data of the North Saluda and Table Rock reservoirs using vessel-based multibeam sonar. The proactive data collection effort will be used to compile a high-density point cloud that will help support the assessment and management of the reservoirs' critical water supply.

"Woolpert will draw on its expertise in bathymetric mapping, comparing newly collected data to data collected in 2013, to provide critical insights into any changes in reservoir storage volume," Maritime Market Director Dave Neff said. "Lidar technology has advanced rapidly in the last decade, and using multibeam sonar will provide a swath of new, high-quality data to help inform Greenville Water's short- and long-term water management planning."

Vice President and Water Program Director James Riddle said that Woolpert will use one of Greenville Water's approved boats to ensure that the water's ecology is largely undisturbed during the acquisition.

Neff said that the contract will be a joint effort by Woolpert's maritime and water resources teams, leveraging and integrating geospatial and environmental best practices.

"This contract will benefit from both the water team's deep understanding of hydrological and environmental dynamics and the maritime team's proficiency in aquatic surveying and technology," Neff said. "By bridging the gap between these specialties as one team, we are looking forward to providing exceptional, comprehensive support for Greenville Water and its customers."

GeoCue, geocue.com, is pleased to announce the addition of The LiDAR Pros (TLP) to its growing distribution network. Based in Las Vegas, Nevada, The LiDAR Pros will serve as a key distributor covering Nevada, Utah, Idaho, Southern California, and Western Arizona providing TrueView 3D Imaging Sensors, fully integrated lidar systems from Microdrones, and LP360 LiDAR Processing Software.

The LiDAR Pros, a startup powered by Sundance Media Group (SMG), brings over 50 years of industry expertise to the table. Specializing in NDAA-compliant UAS products and offering a "white glove" experience with lidar and photogrammetry workflows, The LiDAR Pros caters to clients in the Departments of Transportation, AEC (Architecture, Engineering, and Construction), and public safety organizations seeking precision measurement aerial technologies.

"We aim to provide a seamless experience for our customers, from training to final delivery," said Douglas Spotted Eagle, head of Marketing/Client Relationships at The LiDAR Pros. "With a focus on NDAA-compliant products, we proudly offer the full Microdrones and GeoCue lineup. Teaming up with Sundance Media Group allows us to provide unparalleled training expertise. Through this collaboration, we will offer a 'try-before-you-buy' approach, providing actual paid services and full deliverables. LP360 processing software will serve as the backbone of our offerings, ensuring efficiency and accuracy in our workflow."

Jennifer Pidgen, Owner, and COO of Sundance Media Group, commented on the strategic importance of the collaboration, saying, "We believe that there's significant opportunity in the industry right now because not everyone understands lidar. Our goal is to address challenges, fears, concerns, and elevate the understanding of lidar and the opportunities that aerial data capture can provide."

Aaron Beach, the Western Representative for GeoCue has worked with Douglas for many years and praises the new approach. "They've brought together a team of seasoned experts with extensive backgrounds in the lidar industry, many of whom have also excelled in complementary fields," said Beach. "Their collective experience spans over 80 years across various verticals, allowing The LiDAR Pros to bridge the knowledge gap for their clients, and show them how to leverage lidar and photogrammetry to their fullest potential."

GeoCue's partnership with The LiDAR Pros emphasizes its commitment to providing high-quality lidar solutions to customers across various industries. With The LiDAR Pros' extensive experience and dedication to client satisfaction, this collaboration will drive innovation and streamline workflows for aerial data capture and analysis.

The **Sanborn Map Company** has unveiled an enhanced version of its Sanborn Image Analyst™, a web-based imagery data review application accessible through the Sanborn GeoServe platform. This upgraded application transforms and streamlines the geospatial data review process, offering a single platform and collaborative approach that shortens the QAQC process while improving data quality.

Key features of the updated Image Analyst include efficient real-time collaboration, allowing multiple users to review data simultaneously, view each other's comments in real time, and expedite the review process. Enhanced metadata facilitates issue spotting and resolution, with detailed information on QAQC calls enabling the tracking of active participants and quick identification of patterns and common issues. Centralized data on a single platform speeds up the QAQC workflow by reducing redundant calls and eliminating the need for cross-referencing multiple GIS files edited by different parties.

User controls have been implemented to improve security and management, with Sanborn's Gateway managing access to Image Analyst, providing secure login/password management, and allowing client administrators to assign staff roles and groups. The application supports bringing data into or out of Image Analyst for comparison with local data, allowing client administrators to work with imagery data overlayed by their parcels, roads, and other reference data layers.

The upgraded version also boasts a better data visualization experience with an improved layout, simpler graphics, and more user-friendly interface. Helpdesk integration has been introduced to provide support at every step, with an application-wide helpdesk popup for answering questions and offering tips for optimal usage.

The Sanborn Map Company's commitment to delivering innovative solutions is evident in the upgraded Image Analyst™, promising a more intuitive and collaborative experience for geospatial data review. This enhancement increases efficiency and accuracy across the review process, ultimately improving imagery data for clients.

EVENTS

GIS-Pro 2024: URISA's 62nd Annual Conference, October 7-10, 2024 - Individuals interested in geospatial technology, spatial data science, and location analytics will gather in beautiful and welcoming Portland, Maine for education, training, connections, and solutions. Take advantage of the opportunity to engage and discuss, learn from different perspectives and enjoy relevant and invaluable peer-to-peer interaction. A dedicated volunteer program planning committee is poised to develop an educational agenda that is second to none and relevant in today's challenging environment.

Participate! Submit a presentation proposal by April 8th, https://urisa.org/page/GIS-Pro_Proposals.

CALENDAR

- 2-4 May, **GISTAM 2024**, Angers, France; https://gistam.scitevents.org.
- 13-16 May, **Geospatial World Forum**, Rotterdam, The Netherlands; https://geospatialworldforum.org.
- 20-22 May, **STRATUS 2024**, Syracuse, New York; https://stratus-conference.com/home/.
- 3-7 June, **URISA GIS Leadership Academy**, Seattle, Washington; https://urisa.org/page/URISA_AdvancedGLA.
- 11-14 June, **ISPRS Technical Commission II Symposium — The Role of Photogrammetry for a Sustainable World**, Las Vegas, Nevada; www.isprs.org/tc2-symposium2024.
- 15-19 July, **Esri User Conference**, San Diego, California; www.esri.com/en-us/about/events/uc/overview.
- 18-22 August, **SPIE 2024**, San Diego, California; https://spie.org/OP.

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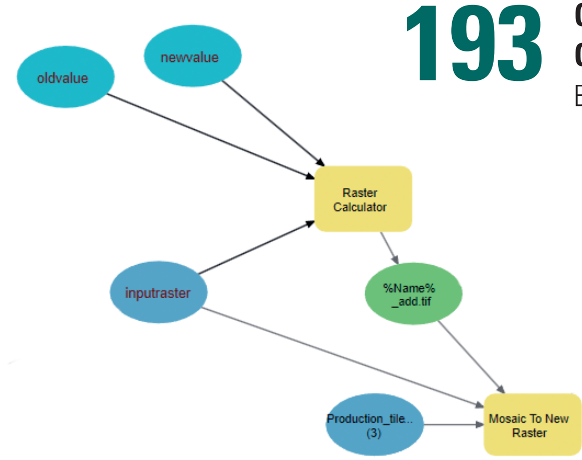

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COVER DESCRIPTION

This month's cover is part of USGS/NASA's Earth As Art 6, https://www.usgs.gov/centers/eros/earth-art.

In addition to their scientific value, many satellite images are simply intriguing to look at. Satellites capture an incredible variety of views of Earth. See the mesmerizing beauty of river deltas, mountains, and other sandy, salty, and icy landscapes. Some might even remind you of actual famous works of art!

The first edition of Earth As Art was published in 2001. The most recent collection, Earth As Art 6, was released in 2019.

Jebel Kissu, in northwestern Sudan, emerges abruptly like an island in the vast Sahara Desert. The plateau is the eroded remnant of a granite dome. The bright linear features are truck tracks, common in the Sahara where there are no paved roads. Resembling graphic novel art style, this image could be an asteroid hurtling toward Earth, burning across a twilight sky.

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Photogrammetric Engineering & Remote Sensing is the official journal of the American Society for Photogrammetry and Remote Sensing. It is devoted to the exchange of ideas and information about the applications of photogrammetry, remote sensing, and geographic information systems. The technical activities of the Society are conducted through the following Technical Divisions: Geographic Information Systems, Photogrammetric Applications, Lidar, Primary Data Acquisition, Professional Practice, Remote Sensing Applications, and Unmanned Autonomous Systems. Additional information on the functioning of the Technical Divisions and the Society can be found in the Yearbook issue of *PE&RS*.

All written correspondence should be directed to the American Society for Photogrammetry and Remote Sensing, PO Box 14713, Baton Rouge, LA 70898, including general inquiries, memberships, subscriptions, business and editorial matters, changes in address, manuscripts for publication, advertising, back issues, and publications. The telephone number of the Society Headquarters is 225-408-4747; the fax number is 225-408-4422; web address is www.asprs.org.

PE&RS. *PE&RS* (ISSN0099-1112) is published monthly by the American Society for Photogrammetry and Remote Sensing, 8550 United Plaza Blvd, Suite 1001, Baton Rouge, Louisiana 70809 . Periodicals postage paid at Bethesda, Maryland and at additional mailing offices.

SUBSCRIPTION. *PE&RS* is available as an e-Subscription (single-site and multi-site licenses) and an e-Subscription with print add-on (single-site license only). PE&RS subscriptions are on a calendar-year, beginning in January and ending in December.

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The rate for a multi-site e-Subscription for the USA/Non-USA is $1040 USD plus $250 USD for each additional license, for Canadian* is $1092 USD plus $263 for each additional license.

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MEMBERSHIP. Membership is open to any person actively engaged in the practice of photogrammetry, photointerpretation, remote sensing and geographic information systems; or who by means of education or profession is interested in the application or development of these arts and sciences. Membership is for one year, with renewal based on the anniversary date of the month joined. Membership Dues include a 12-month electronic subscription to *PE&RS*. Annual Individual Membership dues are $175.00 USD and Student Membership dues are $50.00 USD. A tax of 5% for Canada's Goods and Service Tax (GST #135123065) is applied to all members residing in Canada.

GIS Tips & Tricks

By Chloe Eaton, Zachary Winters, and Al Karlin, Ph.D., CSM-L, GISP

Enhance your GIS Experience with Easily Overlooked Features

As we are writing this column from Florida, it is early January, and the trees are beginning to leaf out. I am reminded that spring is still three months away. So, looking forward to the spring, we are thinking of helpful, hidden (aka Easter eggs), and not-so-obvious features that are easy to overlook in GIS software programs. With the help of my colleagues, Chloe Eaton and Zac Winters, we compiled three GIS Tips and Tricks to increase your GIS workflow efficiency using not-so-obvious features.

Tip #1 — ModelBuilder with Geoprocessing Tools and Variables Chloe Eaton works with raster analysis in ArcGIS Pro and often needs to analyze multiple rasters using the same workflow. This is an ideal scenario to construct a ModelBuilder model, which can include both geoprocessing tools and variables to streamline a repetitive workflow process.

The ModelBuilder Model (Figure 1) adds a new value to a raster dataset using a Raster Calculator expression, then takes that output and Mosaics it to a new raster, builds the raster attribute table, adds a colormap, and finally deletes all the intermediate files. The model reduced the time for this repetitive task from 10 minutes to less than 45 seconds, reduced errors, and increased efficiency.

TIP #2 — Keyboard Shortcuts An "easy to forget" feature involves Keyboard Shortcuts. As most GIS software programs are based in the Microsoft Windows environment, we often forget that the standard Microsoft keyboard shortcuts (e.g. <CTRL>-C for copy, <CTRL>-V for paste, <CTRL>-A for select all, <CTRL>-S for save, etc.) work in the GIS environment too. In addition, each software package typically has a group of its own "default" keyboard shortcuts; usually accessible through the "Help" feature of the software or as a PDF. Most software packages also provide some way to customize or create keyboard shortcuts.

In ArcGIS Pro 3.2 — The Esri ArcGIS Pro Resources page provides both videos and tables of the "standard" keyboard shortcuts (https://pro.arcgis.com/en/pro-app/latest/get-started/arcgis-pro-keyboard-shortcuts.htm). My GIS students are always amazed when I show them the Map navigation shortcuts because they work no matter to the current function being used. These include: Z (zoom continuously), O (Orient the view North), U/J (Zoom Out /Zoom in), and C (override the active tool with the "Explore/Pan" tool).

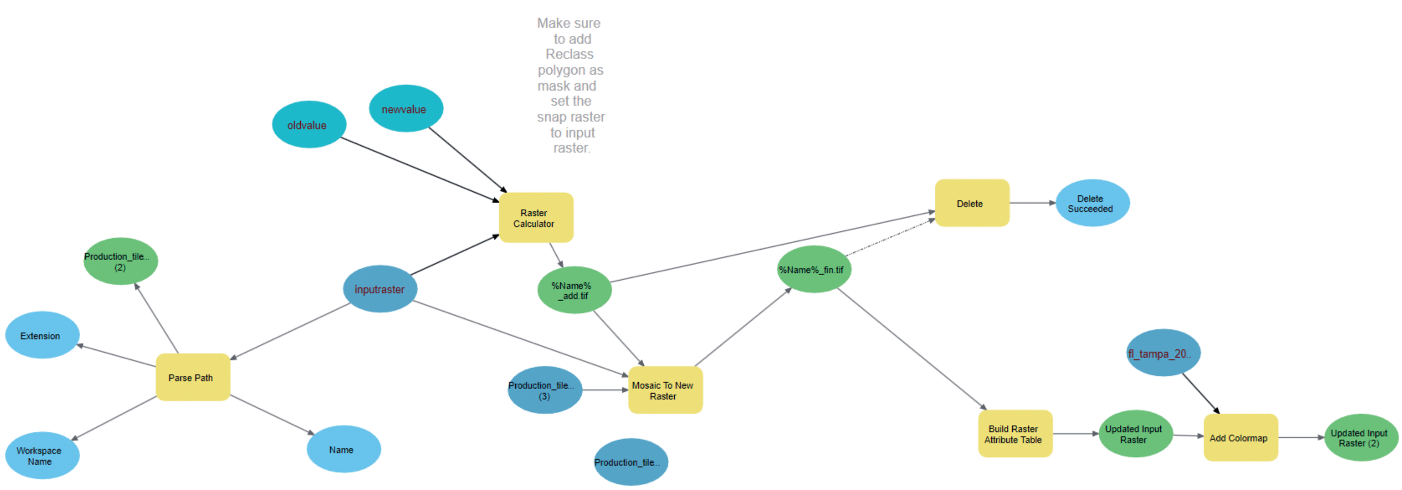


Figure 1. Esri ModelBuilder model incorporating both Geoprocessing tools and variables.

Photogrammetric Engineering & Remote Sensing
Vol. 90, No. 4, April 2024, pp. 193-196.
0099-1112/22/193-196

doi: 10.14358/PERS.90.4.193

Four steps to create a custom keyboard shortcut include:

1. Press the F12 key anywhere in the application.
2. In an open project, click the Help tab on the ribbon.
3. In the Customize Group click "Shortcuts" (Figure 2) to open the Keyboard Shortcuts dialog box.

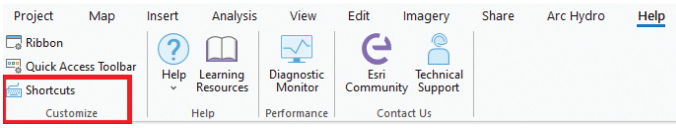


Figure 2. The ArcGIS Pro 3.2 Customize group highlighting the Shortcuts option on the Help ribbon.

"Modeling Magic: Use ArcGIS Pro Model builder for your tedious tasks!"

Chloe Eaton

In the Keyboard Shortcuts dialog box, press the "Add New Shortcut" button and follow the directions to add the custom keyboard shortcut. For features having a default Keyboard Shortcut, you can remove the shortcut (X on the dialog box) or modify it to your preference (Figure 3).

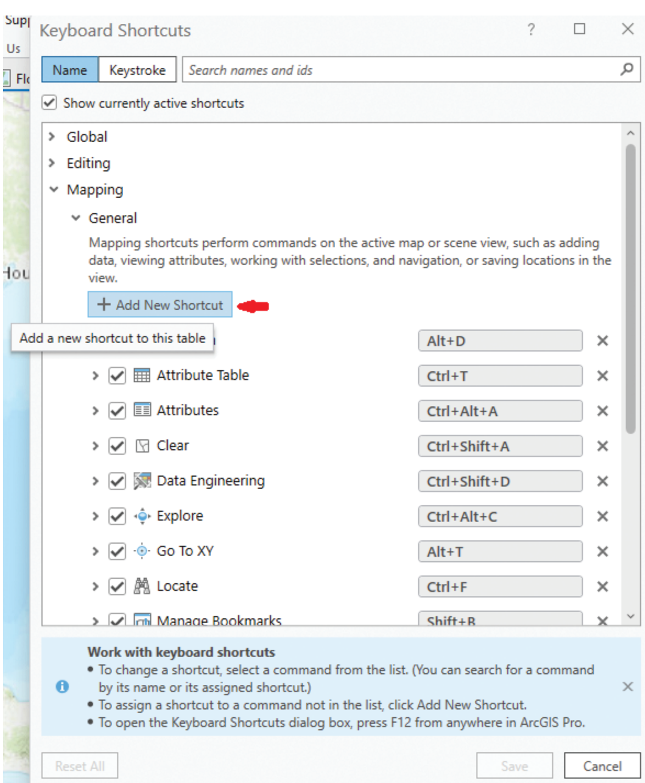


Figure 3. The ArcGIS Pro 3.2 Keyboard Shortcuts dialog box with the "Add New Shortcut" button highlighted.

In QGIS 3.32.2 (Lima) — Most QGIS functions are accessible through Keyboard Shortcuts, but I could not find a PDF listing. However, Open School Maps provides a web-link to the most frequently used QGIS keyboard shortcuts (https://openschoolmaps.ch/lehrmittel/qgis_cheatsheet/qgis_cheatsheet_english.htm).

In the QGIS application, a complete listing of the "default" Keyboard Shortcuts is obtained from the Menu bar (Figure 4), then choosing "Settings" and then "Keyboard Shortcuts". This opens the Keyboard Shortcuts dialog box showing all of the default keyboard shortcuts (Figure 5).

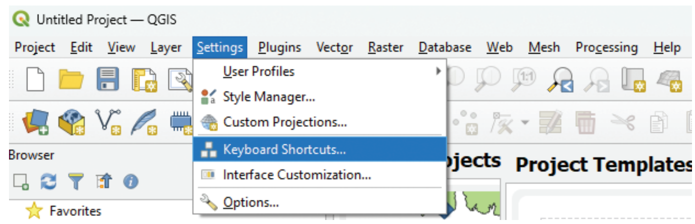


Figure 4. The Settings menu is QGIS 3.32.2 showing the Keyboard Shortcuts option.

To create a custom keyboard shortcut from the Keyboard Shortcuts dialog box,

1. Open the Keyboard Shortcuts... dialog box (Figure 5),

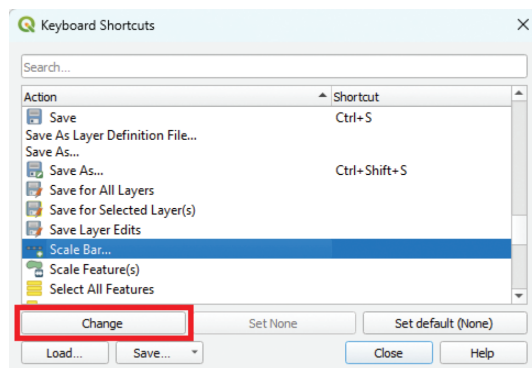


Figure 5. The QGIS 3.32.2 Shortcuts Dialog Box. The selected feature, Scale Bar... does not currently have a shortcut key sequence.

2. Select the QGIS feature that you want to assign a keyboard shortcut, (ex. Scale Bar...)
3. Press the "Change" Button, and
4. Assign a keyboard sequence to the feature.
5. NOTE: If you choose a feature that has a default shortcut, you can modify it using the "Change" button.

In Global Mapper v25.0 — As with ArcGIS Pro and QGIS, Global Mapper also provides multiple default Shortcut Keys (=Keyboard Shortcuts). The PDF listing can be found at:

https://www.globalmapper.it/helpv11/Global_Mapper_Shortcut_Key_List.pdf

As in QGIS, Global Mapper Shortcut Keys and functions are accessible through a dialog box.

1. From the Favorites Menu Bar, select the "Set up Favorites Shortcut Keys..." option (Figure 6),

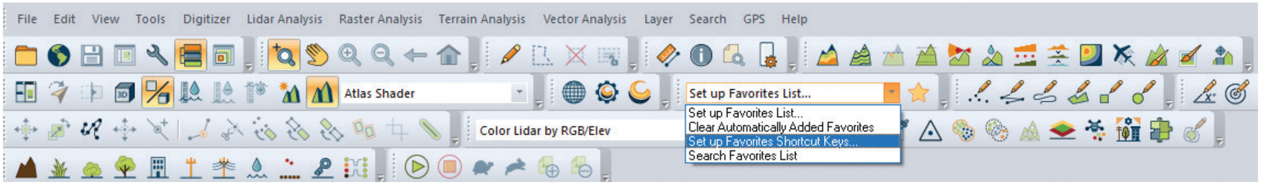


Figure 6. Global Mapper v25 Favorites Menu bar with the "Set up Favorites Shortcut Keys" option selected.

2. From the Shortcut Keys Setup dialog, use the dropdown selector to select the Global Mapper function to customize (Figure 7) and

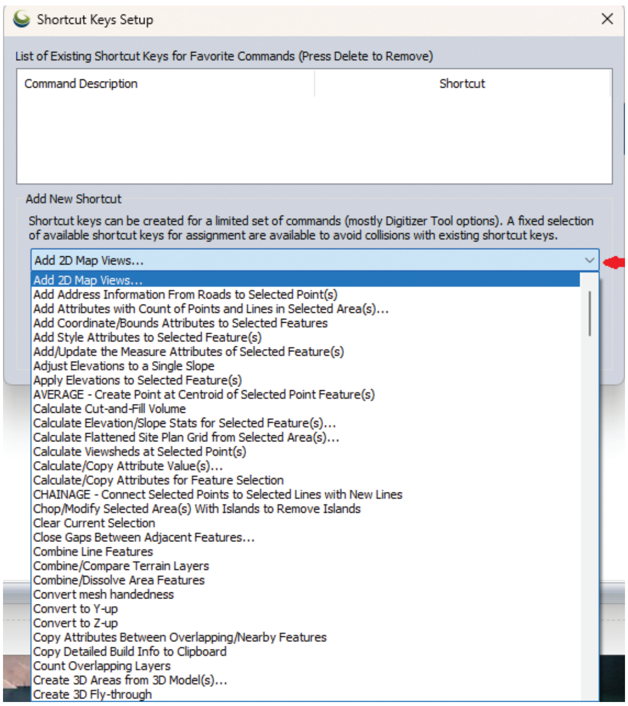


Figure 7. The Global Mapper v25.0 Shortcut Keys Setup dialog box.

3. Assign a key sequence to the feature. Notice that Global Mapper limits both the features and the key combinations available so as not to result in collisions with existing shortcut keys.

TIP #3 — CUSTOMIZING YOUR INTERFACE WITH CUSTOM TOOL TABS AND GROUPS The last "easy-to-forget" feature of ArcGIS Pro for this column is creating custom tool tabs and groups to facilitate your workflows. Zachary Winters often uses tools that are scattered throughout various tabs and remembering where each tool is and what tab it is under can add time and hassle to any project. A somewhat "hidden" method Zac found to alleviate this issue is to create custom tabs on the ArcGIS Pro ribbon or groups within an ArcGIS Pro tab that he typically uses. This allows him to have his commonly used tools all in one place and keeps him focused on the task at hand. The following steps show how to create a custom tab, and how to add tools to the tab. It is just as easy to create a custom Group on an existing Tab.

To create a Custom Tab or Group (within a Tab)

1. Click the drop-down menu located in the Quick Access Toolbar (Figure 8).

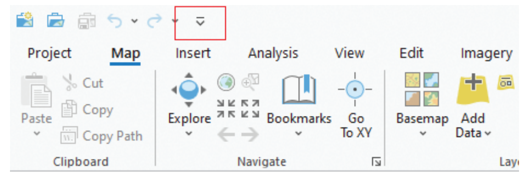


Figure 8. The ArcGIS Pro Customize Quick Access Toolbar dropdown.

2. In this menu, select "Customize the Ribbon" (Figure 9) to open the Options dialog box (Figure 10),

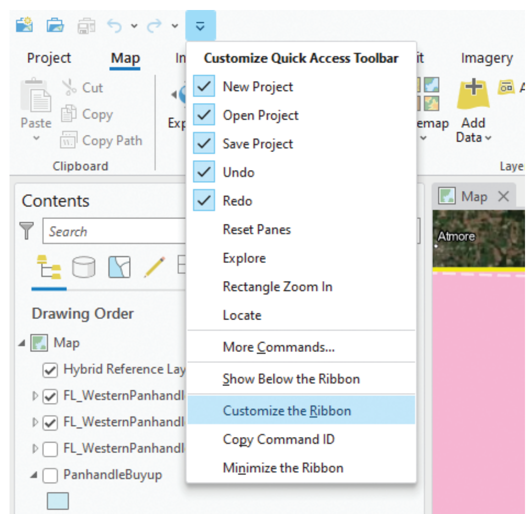


Figure 9. Available options on the Customize Quick Access Toolbar showing the "Customize the Ribbon" option.

3. On the right side of this window, select "New Tab" or scroll to the existing tab in which you'd like to create a new Group, and select it to highlight the tab. In this example, I have the Edit Tab selected and opened, but will create a New Tab by clicking the "New Tab" button (Figure 10) rather than creating a New Group on the Edit Tab (my Edit Tab is pretty full already.)

NOTE: Clicking the New Group with the Edit Tab selected will create the New Group on the Edit Tab.

4. Select the commands or tools to add to this New Tab by scrolling to them in the left pane and clicking the Add button in the center (Figure 10). In this example, I added the Measure, Export Raster, and Explore tool to my custom tab (Figure 11).

   Notes:

   - The default to this window (Choose commands from) is to show "Popular Commands" (Figure 10). If you are unable to find the tool you need, switch this setting to "All Commands" (Figure 11), which will provide a search bar to help filter the options.
   - By selecting an item in the menu on the right, you can also "Rename" items. In this example, I renamed the "New Tab" (Custom) to "Zacs Group" (Custom) before I closed the window.

5. Selecting the OK button on the Options dialog box will close this window, and your new tab should be available on the ArcGIS Pro Ribbon (Figure 12).

If you chose to create a New Group on a selected tab, that new Group will appear on the selected tab on the ArcGIS Pro ribbon. Of course, you can use the up/down arrows on the Options dialog (Figure 11) to position groups on the tab. In this example, I moved the "Zacs Tools" to be next to the Clipboard Group on the Edit tab (Figure 13).

There are three not-so-obvious GIS Tips that can make your GIS-life easier. Happy mapping!

Send your questions, comments, and tips to GISTT@ASPRS.org.

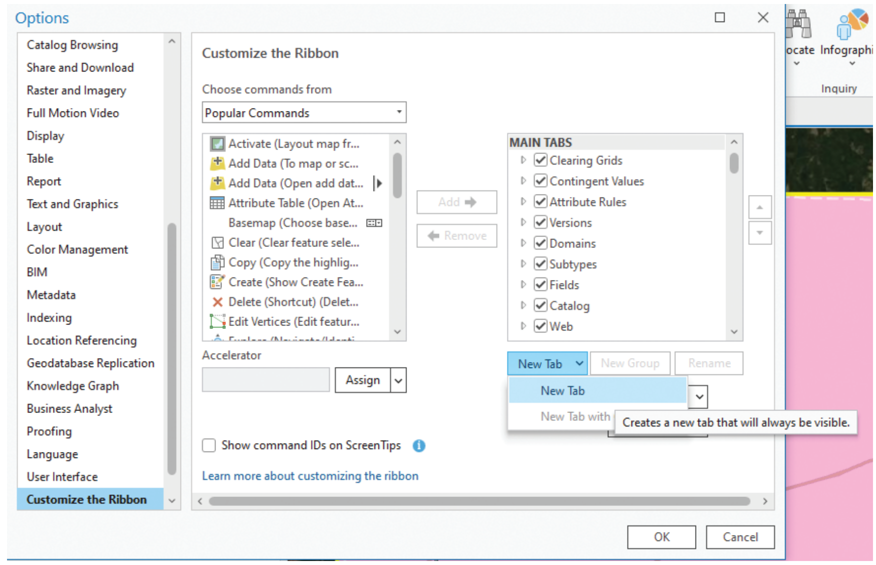


Figure 10. The dialog box on the Customize the Ribbon option with the "New Tab" selected.

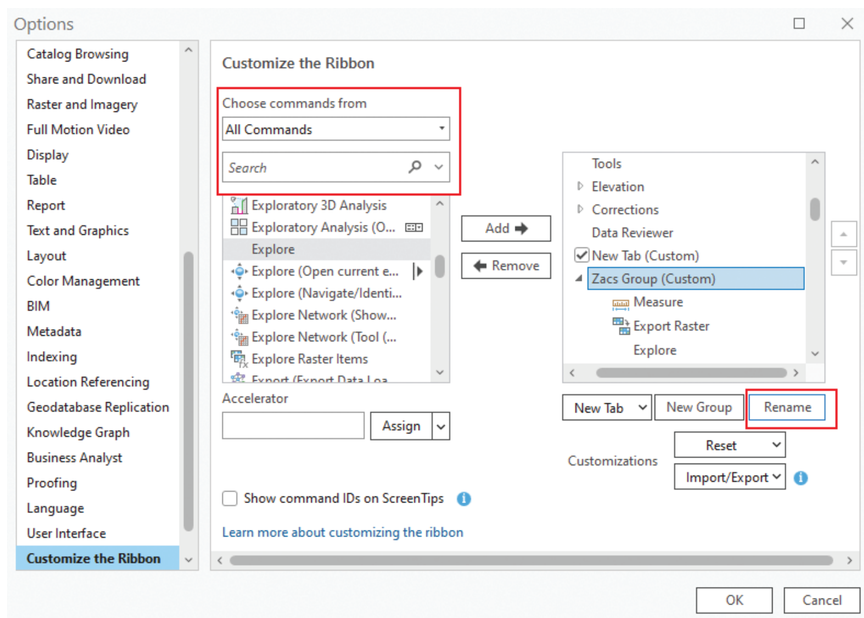


Figure 11. The Customize the Ribbon dialog box showing "All Commands" on the left, the selected features added to the new Tab on the right and renaming the new Tab to "Zacs Group".

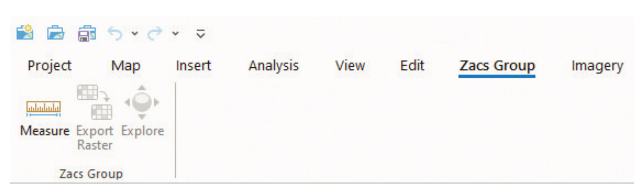


Figure 12. The ArcGIS Pro ribbon with the new "Zacs Group" Tab.

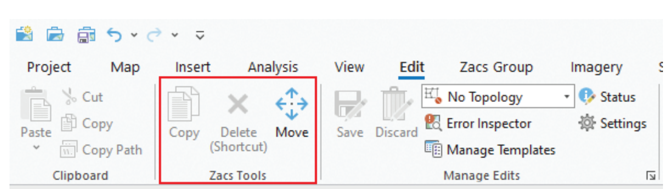
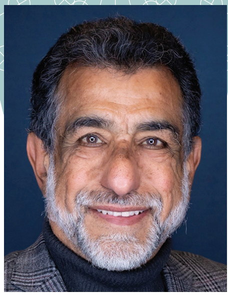


Figure 13. A New Group (Zacs Tools) added to the Edit Tab on the ArcGIS Pro ribbon. Note the new Tab (Zacs Group) to the right of the Edit Tab.

Chloe Eaton is a GIS Analyst with Dewberry, Tampa. Her specialties are image interpretation and land use classification.

Zachary Winters is a GIS Analyst with Dewberry, Tampa. His specialties are image interpretation and NWI mapping.

Al Karlin, Ph.D., CMS-L, GISP is with Dewberry's Geospatial and Technology Services group in Tampa, FL. As a senior geospatial scientist, Al works with all aspects of lidar, remote sensing, photogrammetry, and GIS-related projects.



MAPPINGMATTERS

YOUR QUESTIONS ANSWERED

The layman's perspective on technical theory and practical applications of mapping and GIS

BY Qassim A. Abdullah, Ph.D., PLS, CP**

QUESTION:

Questions: What would you recommend to quantify the relative accuracy for area and distance measurements, from imagery? The new ASPRS Positional Accuracy Standards for Digital Geospatial Data has the section on "Data Internal Precision (Relative Accuracy) of Lidar and IFSAR Data," but would this be the best approach for a 2D orthomosaic as well? The new standard is important, and we want to educate our user community on its concepts and the importance of accuracy, as well as current methods for measuring data. As you know, most drone projects cover small geographic areas, and 30 independent checkpoints for accuracy assessment may not be feasible. A common drone application is measuring changes in the volume of stockpiles, such as a project monitoring a dynamic construction site, where much of the content in the imagery changes daily. Users in this case would need to ensure the accuracy (precision/repeatability) of their 2D and 3D measurements, but may be less concerned about absolute positional accuracy. What advice would you give to these users?

Cody Benkelman, Product Manager for Imagery at Esri (www.esri.com)

Relative accuracy versus data internal precision: First, I would like to bring readers' attention to the fact that in Edition 2 of the ASPRS standard, we changed the term "relative accuracy" to "data internal precision," as many industry professionals do not consider the repeatability in measurements as a standard accuracy measure. Therefore, I will apply the term "data internal precision" when discussing "relative accuracy" in this article.

"in Edition 2 of the ASPRS standard, we changed the term 'relative accuracy' to 'data internal precision,' as many industry professionals do not consider the repeatability in measurements as a standard accuracy measure."

Is there such a term as "relative accuracy" for an orthomosaic? As for your first part of the question, I do not believe that there is a meaningful term for a 2D map's data internal precision. Data internal precision is about repeatability and the internal precision of a dataset or an instrument. Measuring distance or area once on one set of an orthomosaic does not effectively evaluate data internal precision. You can repeat the measurement of the same distance or area multiple times on the same orthomosaic to come up with a data internal precision figure, but this does not represent the map's data internal precision as much as it represents the accuracy of the tool being used to conduct these measurements—ruler, tape, etc.—or the ability of the person to repeat this measurement.

How do you determine data internal precision for a map? To determine the data internal precision of a map, you will need to fly the same area over and over, using the same sensor, same ground controls, same processing software, and same skills of data technician. Once multiple sets of an orthomosaic are produced, the data internal precision of a distance or an area measurement can be established by measuring the same distance or area on different sets of the orthomosaic. But even with that, the many variables in the process make it difficult to relate data internal precision solely to the orthomosaic itself.

"The subject of determining data internal precision can be better understood and reached for lidar, where data internal precision defines the ability of the lidar ranging to measure the same elevation multiple times by different pulses—i.e., a point cloud."

Determining data internal precision for lidar is easier to understand: The subject of determining data internal precision can be better understood and reached for lidar, where data internal precision defines the ability of the lidar ranging to measure the same elevation multiple times by different pulses—i.e., a point cloud. We estimate the data internal precision of lidar by comparing the elevation of a flat, smooth surface from different point clouds or laser pulses. All these pulses or point clouds should result in the same value for the elevation of that horizontal, flat, and smooth surface. However, due to the biases in laser ranging, those elevations will never have the same values. The variation in the elevation values for that surface represents the repeatability or data internal precision of the lidar data.

Photogrammetric Engineering & Remote Sensing
Vol. 90, No. 4, April 2024, pp. 197-198.
0099-1112/22/197-198

doi: 10.14358/PERS.90.4.197

"the best measure to represent data internal precision is to statistically measure the variance or the standard deviation."

What is the best measure to represent data internal precision? In my opinion, the best measure to represent data internal precision is to statistically measure the variance or the standard deviation. Standard deviation is a statistical measure for the fluctuation or dispersion of individual errors around the mean value of all errors in a dataset.

Checkpoints for a drone project; is there a way around it? As for the second part of the question on drone users and the use of independent checkpoints in measuring relative change, I agree that applications such as stockpile monitoring do not need checkpoints to measure every time a volume is computed. However, it is crucial to these operations to make sure that the photogrammetric process that precedes the volume, or the point cloud, generation is repeated from one day to another with the same level of accuracy and precision. To guarantee a repeated level of accuracy for the aerial triangulation and therefore the entire photogrammetric process, one will need to use reliable ground control points and a set of additional independent checkpoints during the aerial triangulation process. The purpose of checkpoints in the aerial triangulation process is to provide evidence of the accuracy of the solution. Relying on the fit to the ground controls in the solution alone is not acceptable because it is a biased measure. That said, although it removes the requirements for independent checkpoints necessary to verify the accuracy of the final volume computations, you still need those checkpoints upfront to assess the accuracy of the aerial triangulation. As you will see, if the user wants to do it right, there is no benefit to eliminating checkpoints from the process; it is a matter of moving it from one phase of production to another. Without assuring that the different volumes generated from one day to another were produced and computed with the same level of accuracy, estimating the changes in the stockpile will neither be accurate nor reliable, and you will never be sure that the 5,000-cubic-yard change in the stockpile (for example) was due to the accuracy of the photogrammetric process or what was actually hauled away.

"To guarantee a repeated level of accuracy for the aerial triangulation and therefore the entire photogrammetric process, one will need to use reliable ground control points and a set of additional independent checkpoints during the aerial triangulation process."

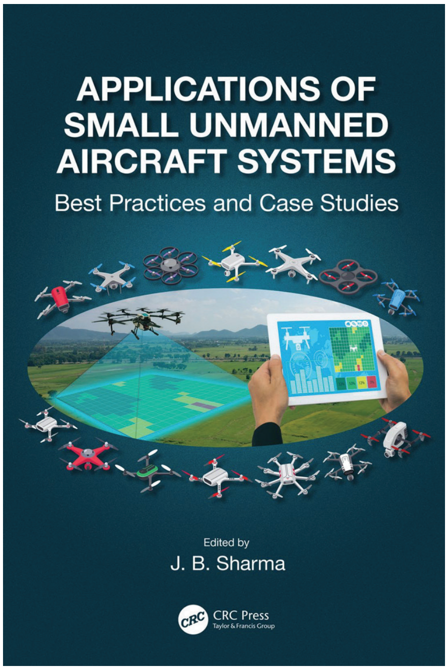
Number of checkpoints and the ASPRS Accuracy Standard: Now I would like to elaborate on the number of checkpoints and how the drone community looks at the requirement of at least 30 checkpoints. The ASPRS standard requirement for this number is modeled after the well-known central limit theorem. According to the central limit theorem, regardless of the distribution of the population, if the sample size is sufficiently large ($n \geq 30$), then the sample mean is approximately normally distributed, and the normal probability model can be used to quantify uncertainty when making inferences about a population based on the sample mean. With that declaration, no one can justify performing a statistically and scientifically valid accuracy assessment with fewer than 30 checkpoints. However, I understand the business environment surrounding drone operations and the size of these projects. If users cannot afford 30 checkpoints, then my advice is to perform the assessment with the maximum number of checkpoints you can afford—but do not skip the assessment. Although it is not a valid statistical sample, fewer checkpoints are better than no checkpoints. Fewer checkpoints at least provide an idea about the data accuracy at the location of those checkpoints. Edition 2 of the standard provides the following accuracy reporting statement for such cases:

If users cannot afford 30 checkpoints, then my advice is to perform the assessment with the maximum number of checkpoints you can afford—but do not skip the assessment."

"This data set was tested as required by ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, v2 (2024). Although the Standards call for a minimum of thirty (30) checkpoints, this test was performed using ONLY __ checkpoints. This data set was produced to meet a ___(cm) $RMSE_H$ Horizontal Positional Accuracy Class. The tested horizontal positional accuracy was found to be $RMSE_H$ = ___(cm) using the reduced number of checkpoints."

The statement clearly declares the test as not meeting the ASPRS standard, but it reports the number of checkpoints used in the assessment. This statement encourages truth in reporting and at the same time makes users aware of the importance of using a minimum of 30 checkpoints for accuracy assessment.

***Dr. Abdullah is Vice President and Chief Scientist at Woolpert, Inc. He is also adjunct professor at Penn State and the University of Maryland Baltimore County. Dr. Abdullah is ASPRS fellow and the recipient of the ASPRS Life Time Achievement Award and the Fairchild Photogrammetric Award.*



Applications of Small Unmanned Aircraft Systems: Best Practices and Case Studies

308 pages. 2023. CRC Press. ISBN-10: 1032475153; ISBN 13: 978-1032475158. Price on Amazon: Paperback $54.15, Kindle $54.95, Hardcover $128.61.

Reviewed by Connie Krampf, CP, CMS/GIS_LIS, Senior Geospatial Analyst, DroneView Technologies, Bloomfield Hills, Michigan.

Applications of Small Unmanned Aircraft Systems: Best Practices and Case Studies is edited by J.B. Sharma, Ph.D. Dr. Sharma is a professor and the assistant department head of the Physics Department at the University of North Georgia. One of his research interests is small Unmanned Aerial Systems (sUAS).

Applications of Small Unmanned Aircraft Systems: Best Practices and Case Studies includes a total of 12 sections or chapters. Each chapter covers unique, important topics that are crucial for applying sUAS technology in a correct and efficient manner. Each chapter was written by well-respected, knowledgeable academic; experienced professionals and experts in the field.

The book discusses multiple important topics including sUAS data accuracy in photogrammetry workflows, UAS and thematic map accuracy assessment, multi-user concepts and workflow replicability in sUAS applications, the sUAS educational frontier: mapping and educational pathways for the future workforce, federal government applications of UAS technology, sUAS for wildlife conservation – assessing habitat quality of the endangered black–footed ferret, multi–view, deep learning, and contextual analysis: promising approaches for sUAS land cover classification. UAS for nature conservation–monitoring invasive species, small unmanned aerial systems (sUAS) and structure from motion for identifying, documenting, and monitoring cultural and natural resources, new insights offered by UAS for river monitoring, the campus as a high spatial resolution mapping laboratory – small unmanned aerial systems (sUAS) data acquisition, analytics, and educational issues, and flying UAVs in constrained environments: best practices for flying within complex forest canopies.

The book details how broad the areas are for the application of sUAS. Pictures, tables, and mathematical formulas are provided to help to explain and demonstrate the points of view of the authors. Case studies, real project examples and evaluations, research findings, and the great variety of sUAS applications carry throughout. One of the important sUAS applications discussed is sUAS education. In Chapter 4, the author states the significance of sUAS education and the process of mapping the educational and professional development needs of the sUAS industry. A detailed reference follows each chapter to provide the user with additional information about that chapter's topic.

With the advance of the technology, sUAS is capable of acquiring data with low cost, time efficient and safer ways when compared with other methods for highly accurate mapping production and data analysis. But there is some confusion and misunderstanding about the sUAS capabilities, operations, and mapping products accuracies. *Applications of Small Unmanned Aircraft Systems: Best Practices and Case Studies* comes at the right time and is much needed for this evolving industry. As the author of the first chapter points out: "…UAS operators need to understand that utilizing UAS for mapping practices requires a thorough knowledge and appreciation of the photogrammetric process and the factors effecting such processes……." The book provides for complete guidelines from drone mapping project planning to the final data production, analysis and accuracy assessments. Users can also find information about sUAS software and hardware

Photogrammetric Engineering & Remote Sensing
Vol. 90, No. 4, April 2024, pp. 199-200.
0099-1112/22/199-200

doi: 10.14358/PERS.90.4.199

such as platforms and cameras in the applications. The book can be used as a textbook for undergraduate and graduate students as well as a reference for practitioners in sUAS applicable fields.

The cover is well designed and catchy is the contents well organized so that the reader can follow along with ease. Case studies and examples presented were selected to support the authors' points of view. The book is published in paperback, hardcover and kindle multiple formats. This particular review is based on the Ebook (EPUB) format that required a little more effort to follow for one who is used to reading hardcopy. A very minor suggestion is to use sUAS as a term throughout the entirety of the book instead of the terms UAS or UAVs used interchangeably from chapter to chapter. Regardless, the reviewer highly recommends this book for students and sUAS related professionals.

NEW ASPRS MEMBERS

ASPRS would like to welcome the following new members!

Azeez Adewale Adejumo
Zainab Oyinkansola Akinsemoyin
Troy L. Ballard
Nicholas Burchett
Joel Connolly
William Halley
Seda Nur Gamze Hamal
Todd Harris
Trevor Hildebrand
Andrew Hill
Thomas G. Hughes
Mike Kitaif
Sydney LaMothe
Ryan Lennon
Ashley Lynch
Timothy John Lyons
Jonathan Markel
Nelson Mattie, Ph.D.
Mario Montagna
Mike Morellato
Evan O'Brien
Eniola Onatayo
Diana N. Phillips
Ryan Prasad
Austin Jay Riley
Randal Rodger
Simone Sayuri Sato, Ph.D.
John F. Savarese, III
Fiona M. Smith
Maggie Sobolewski
Mackenzie Soligon
Michael Tandarich
James Tobler
Matthew Veth
Reid Wilson
Caitlyn Young

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ASPRS 2024 YEARBOOK

At Geo Week, February 10–12, 2024, Denver, Colorado

Geo Week 2024 brought together a remarkable assembly of professionals from across the globe, with over 3,400 registrants hailing from 45 different countries. The event was a convergence of expertise, innovation, and collaboration in the field of geospatial sciences and technologies.

Key Highlights

Workshops

ASPRS organized eight workshops on February 11, with over 340 registrants. Participants lauded the workshops for their engaging instruction and approachability, with one attendee remarking, "Very well instructed, they were engaged and helped make a complex subject more approachable."

Sessions and Posters

14 sessions were held during the event, covering a wide range of topics pertinent to the geospatial community. Additionally, the Academic Hub featured multiple poster presentations, showcasing the latest research and advancements in the field.

Committee Meetings

Various committees, regions, and councils convened for in-person meetings, fostering meaningful discussions and collaborations on important industry matters.

Awards Ceremony

The Geo Week Joint Award Ceremony recognized the outstanding contributions of seven ASPRS professionals, who were honored with prestigious awards such as the Estes Memorial Teaching Award, Fellow Awards, Photogrammetric Fairchild Award, Lifetime Achievement Award, and the Outstanding Technical Achievement award.

Annual Business Meeting

At the ASPRS Annual Business Meeting, new officers, including President Bandana Kar, were installed. ASPRS Society Awards and Scholarships were awarded to professionals and students.

Exhibit Hall

The conference boasted a vibrant exhibit hall featuring around 200 exhibitors. Attendees had the opportunity to explore the latest advancements in geospatial technology and services while networking and socializing at the ASPRS booth.

Achievements

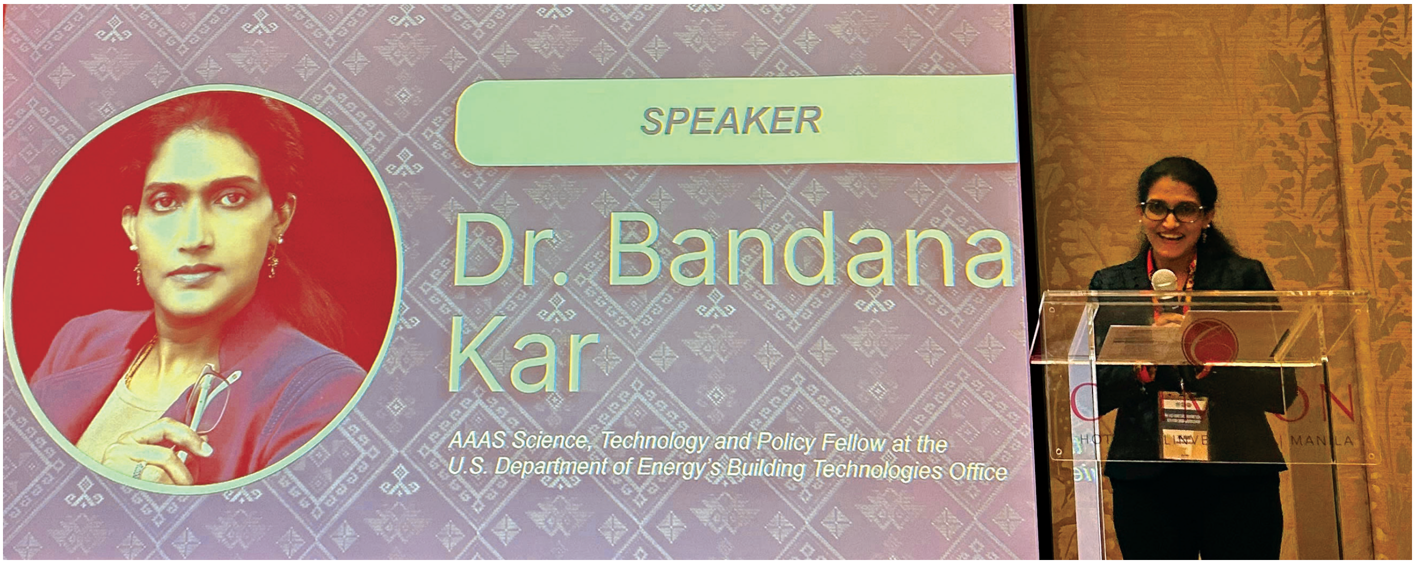
- Geo Week 2024 witnessed a significant turnout of professionals from diverse backgrounds, facilitating invaluable knowledge exchange and networking opportunities.
- The workshops, sessions, and poster presentations provided attendees with insights into cutting-edge research and practical applications within the geospatial domain.
- The recognition of outstanding professionals through awards and the installation of new officers underscored the commitment of ASPRS to honor excellence and leadership within the community.

Geo Week 2024 was a resounding success, thanks to the collective efforts of organizers, sponsors, speakers, and attendees. The event served as a premier platform for advancing the field of geospatial sciences and technologies, fostering collaboration, and celebrating achievements. With such a remarkable turnout and impactful activities, Geo Week continues to be a cornerstone event for the global geospatial community.

ASPRS Presidential Address

Leading Next Generation Geospatial Science and Technology

March 12, 2024
Bandana Kar, PhD



I am honored to serve as this year's (2024) ASPRS President. ASPRS has been one of my professional societies for the past 20 years. When I joined the society as a graduate student in early 2000, the geospatial science and technology landscape looked quite different. Many technologies that we now take for granted, such as having GNSS and lidar on our smart phones along with stereoscopic cameras to generate 3D pictures and videos in real-time, drones to capture imagery at any given time for any purpose, high resolution imagery to detect individual buildings, cloud and edge computing to deliver real-time solutions to end-users, did not exist. As Claire Rutkowski mentioned in her keynote at the 2024 GeoWeek Conference, we are at a tipping point where convergence of these technologies is possible to address societal challenges through the lens of disciplinary intersectionality. With the emergence of Industrial Revolutions 4.0 and 5.0, ASPRS, a leader in geospatial science and technology since its inception in 1934, is well situated to bring together academic, industry, and government partners to lead us on the trajectory of next generation geospatial science and technology growth.

For the society to succeed, we the members have to make a collective effort to invest in the next generation of professionals and researchers, which has always been a focus of ASPRS. Unlike in the past, students now are more interested and driven to develop holistic solutions to societal challenges, from climate extremes, to environmental justice, energy security and community resilience. The leaders of Student Advisory Council (SAC) and Early Career Professionals Council (ECPC) have done an exceptional job in attracting and providing young talents a platform to connect with experienced researchers. Given that the society gives awards and scholarships to promote excellence among students and early-career researchers, one of my primary goals is to work with SAC and ECPC to increase student engagement within ASPRS, thereby broadening our member base. While creating new student chapters will meet this goal, it is equally important to expand networking, mentoring, education and outreach activities by offering microlearning modules to assist students with job search, interview, and professional development as they transition into early-career professionals. We should also build on the partnerships with universities and university-led programs, such as AmericaView, to attract students.

The divisions are the intellectual pillars of the society. While the divisions have been successful in developing standards and best practices to ensure convergence of technologies, it is essential for the divisions to come together via interdisciplinary working groups and efforts. The regional chapters and the Sustaining Members Council (SMC) are also crucial for the success of the society as they provide a platform for members from different sectors and agencies. It is imperative to work with these chapters and existing councils to develop a cohesive message for the members and streamline the certifications to meet member needs as they contribute to workforce. Another priority for me is to connect with Regional Officers' Council and SMC to determine activities that will promote interaction among these entities as well as recruitment and retention of members beyond early-career.

We should not forget *Photogrammetric Engineering and Remote Sensing* (*PE&RS*), the flagship journal of the society, which is also a top peer-reviewed journal. As the journal transitions into open-access to keep pace with the evolving publication model, we should take note of the PE&RS awards that recognizes and provides monetary awards to excellent scientific research. Considering that the awards are given to researchers irrespective of their affiliation with the society, we should connect with these researchers and invite them to be part of ASPRS.

ASPRS has evolved over the years to accommodate changes in the geospatial science and technology domain. While in mid-2000 ASPRS had few female role models, now the society includes more female members and leaders. In the past decade, the society had 4 female presidents including myself. The current distribution of female members may not seem significant, but the society has created the DEI Committee that I was lucky enough to lead with the past president Christopher Parish. The intent of the committee is to work with divisions, councils and regional chapters to increase diversity and enable the path to leadership. Of course, being a leader requires commitment and involvement. Throughout my journey since my graduate student days, I have been engaged in society activities starting with organizing sessions and reviewing abstracts for annual meetings before I became the GIS Division Director almost a decade ago. I invite you to contribute by leading events within your local ASPRS region by volunteering at conferences or by joining the monthly Brainstorming-to-Action meetings. ASPRS provides opportunities for members to be involved in different activities, thereby laying a path to leadership. We should build on these benefits and get involved in the society to make the vision of what future ASPRS should look like a reality.

I would like to express my gratitude to colleagues and past presidents – Lorraine Amanda, Dr. Chris Parish, and Dr. Jason Stoker for their leadership over the years. My sincere thanks to my colleagues on the Board of Directors, Committee and Council Chairs, Division Directors, Region leaders, ASPRS Executive Director - Karen Schuckman, Editor-in-Chief and Assistant Director of Publications of *PE&RS*- Alper Yilmaz and Rae Kelley, and Digital Publications Manager - Matthew Austin, for their contributions to ASPRS. I would like to thank all members of ASPRS for your participation in this exceptional organization and for giving me the opportunity to represent you as the 2024 ASPRS President! Last but not least, I would like to thank Michael Hodgson, John Jensen, Marguerite Madden, Anne Hillyer, Rebecca Morton, and J. B. Sharma and many others who I have looked up to during my journey so far within the society.

AWARDS AND SCHOLARSHIPS

Through the ASPRS Foundation, ASPRS provides support to undergraduate and graduate student members of the society through their Scholarship program, and recognizes professionals who are contributors to the field of spatial and image sciences. Awards for Outstanding Papers, Professional Achievement, and Service activities are determined by committee selection; scholarships and academic awards are also determined by committee selection but are chosen from current applications. A comprehensive review of the awards program is available on the ASPRS webpage: https://www.asprs.org/education/asprs-awards-and-scholarships.

ASPRS AWARDS

ASPRS Fellow Award

2024 recipients: Joseph Messina, Becky Morton, Amar Nayegandhi, Greg Stensaas

Joseph Messina

Dr. Joseph Messina has served as Dean of the College of Arts & Sciences at the University of Alabama since 2019. Messina served in the U.S. Army working with early GIS and TACFIRE systems in the Field Artillery. After his Honorable Discharge, he earned a BA in Biology (1992) and an MS in Geographic and Cartographic Sciences (1994) from George Mason University. Messina was subsequently employed as a remote sensing scientist at the SPOT Image Corporation, serving as part of the working group that led to the development and release of the GeoTIFF data format. Messina developed and published natural color composite algorithms adopted by all major remote sensing software companies and was the first European Space Agency RADARSAT product manager for North America. Returning to academia, Messina completed his Ph.D. at UNC-Chapel Hill (2001) and then became an Assistant Professor at Michigan State University in the Department of Geography and at the Center for Global Change and Earth Observations. Messina proceeded through the academic ranks to Professor, ultimately becoming the Associate Dean of Research, and then Assistant Vice-President of Research at MSU before his shift to Alabama. He has been funded by a range of agencies and organizations including NASA, the National Science Foundation, National Institutes of Health, U.S. Agency for International Development, U.S. Department of Defense and the Bill & Melinda Gates Foundation. He has authored influential papers, including in *PE&RS*, on drug war remote sensing, land-use/land-cover change, climate change and vector-borne disease, and remote sensing methods. Messina has taught GIS, remote sensing, and geocomputation to undergraduate and graduate students with recognition for this teaching ability coming through accolades such as the AT&T technology enhancement award for classroom innovation in geocomputation. His 25+ advisees have pursued careers in the military, intelligence communities, higher education, and private sector.

From 2003–2005 Messina served on the ASPRS National Committee on Membership, which created an initiative and materials for a national recruiting campaign. He traveled throughout the Great Lakes region visiting universities to promote the formation of ASPRS student chapters, including reactivating and serving as advisor to the long-dormant Michigan State University ASPRS student chapter. Messina has been an active author and reviewer for *PE&RS*, has served as co-editor of a special issue for the journal, and has organized and chaired sessions at the ASPRS Annual Meetings.

Rebecca A. “Becky” Morton

Rebecca A. (Becky) Morton is currently President and Chief Executive Officer (CEO) of GeoWing Mapping, Inc., Richmond, California. Morton attended the University of Arkansas in Fayetteville where she earned a BS degree in Psychology in 1979. She subsequently undertook additional training in computer science, surveying, and mapping at the South Dakota School of Mines and Technology. Morton has received multiple awards from ASPRS including Presidential Citations (2009, 2011), Outstanding Service Award (2013), and the Claude Birdseye Award (2018).

Morton has practiced photogrammetry for 30+ years through her employment at Horizons, EarthData, Towill, and GeoWing Mapping, beginning as a Programmer/Analyst responsible for systems integration and the translation of mapping data followed by positions as Orthophoto Systems Manager, Director of Business Development, Regional Manager, and Senior Program Director. Morton also established and ran a small GIS company, RAMCad, for 8+ years to provide historical georeferenced imagery to the U.S. Army Corps of Engineers and GIS application development services for numerous clients. Most recently, she co-founded GeoWing Mapping, Inc., a small aerial mapping firm that applies both manned and unmanned aircraft systems to acquire data for its photogrammetric operations. Morton is certified by ASPRS as a Photogrammetrist and as a Mapping Scientist GIS/LIS.

Morton has been an active member of ASPRS since 1995, providing service to the Society at the Regional and National levels, including serving as the ASPRS National President from 2017-18. Morton served on the ASPRS Board of Directors from 2008-2010 and 2012-2018, and was a member of the ASPRS Executive Committee from 2012-2018. She currently serves as a Trustee for the ASPRS Foundation and is a Regional Director of the Pacific Southwest Region. Morton has been active on several ASPRS committees including the Licensure Exam Writing Committee, Evaluation for Certification Committee, the Kenneth J. Osborn Memorial Scholarship Committee, and the Lidar Committee. From 2006-2010, she served as the Director of the Photogrammetric Applications Division, and from 2010-2014, she served as Director of the Professional Practice Division. Under her direction, the Society developed standards for lidar data, and for mapping accuracy. In 2014, she was appointed to Chair the ASPRS Unmanned Aircraft Systems (UAS) Task Force, which led to the formation of the UAS Division. She also served on several ASPRS procurement guideline committees, culminating in the publication of the ASPRS Procurement Guidelines for Geospatial Mapping Products and Services in 2014.

In addition to her ASPRS leadership responsibilities, she has served as Membership Chair for the Oakland-Piedmont (California) Branch of the American Association of University Women. From 2008-2010, she served as Treasurer for the Bay Area Automated Mapping Association (BAAMA), the local URISA Chapter. Morton served as conference chair for the UAS MAPPING RENO symposia held in 2014 and 2015, in Reno, NV.

Amar Nayegandhi

Mr. Amar Nayegandhi is Senior Vice President – Geospatial and Technology Solutions and Technology Market Segment Leader at Dewberry. Nayegandhi is an expert in topographic and bathymetric lidar data acquisition and processing and has over 23 years of experience in the research and private sector. He has developed original data processing algorithms and software for airborne lidar sensors, and processed and analyzed data from terrestrial, airborne and satellite instruments. Nayegandhi has presented research at more than 100 international conferences and technical workshops, as well as authoring 17 refereed manuscripts in professional publications and more than 65 reports for the U.S. Geological Survey. Nayegandhi was the primary author of a report evaluating new lidar technologies—Geiger Mode and Single Photon—for USGS's 3D Elevation Program and co-edited the *ASPRS Digital Elevation Model Technologies and Applications: The DEM User's Manual,* 3rd Edition, authoring the chapters on Airborne Topographic Lidar and Airborne Lidar Bathymetry. He also co-authored the USACE EM 1110-1-1000, *Photogrammetric and Lidar Mapping*.

Prior to joining Dewberry, Nayegandhi was a Project Manager and Remote Sensing Applications Developer with Jacobs Technology, contracted to the USGS Coastal and Marine Geology Program. From 2001–2011, he managed operations and was involved in R&D of the NASA/USGS EAARL sensor for the USGS Coastal Program. In 2011–2012, he developed Dewberry's Lidar Processor (DLP) to process airborne bathymetry data acquired with the Riegl VQ820G, which included correcting for refraction of the green lidar signal as it traversed through the water column using water surface returns from near-infrared lidar.

Nayegandhi earned a Bachelor's degree in Electrical Engineering from the University of Mumbai (1998) and a Master's degree in Computer Science from the University of South Florida (2001). He is an ASPRS Certified Photogrammetrist, Certified Mapping Scientist – Remote Sensing, and Geographic Information Systems Professional (GISP). Nayegandhi has been an active member of ASPRS since 2005, served as the Director/Assistant Director of the ASPRS Lidar Division (2016-2020), and he co-authored the LAS domain profile for topobathy lidar sensors. Nayegandhi currently serves on the MAPPS Board of Directors.

Greg Stensaas

Greg Stensaas has worked with remote sensing systems and data for over 38 years, including service with the United States Geological Survey (USGS) Earth Resources Observation and Science (EROS) Cal/Val Center of Excellence (ECCOE) and the Landsat Program, NASA Earth Observation System Distributed Information System (EOSDIS), and U.S. Army and Air Force. Stensaas spent 24 years at the EROS Center in Sioux Falls, SD. He was project manager for the EROS ECCOE, Requirements Capabilities & Analysis for Earth Observation, and Remote Sensing Technologies projects where he was responsible for understanding system and sensor capabilities, user requirements, system/product characterization, and camera calibration and managing the USGS Optical Science Laboratory and USGS Camera Calibration Facility. Stensaas gained extensive system engineering, program management, and information systems experience through systems exploitation, development, simulation, and test experience as an electronics engineer and operations research analyst for the U.S. Army and the Air Force, Raytheon principal engineer for the NASA Earth Observing System Distributed Active Archive Center, and systems engineer for the USGS Landsat Data Continuity Mission and the Satellite Cross-calibration Radiometer.

Stensaas developed many procedures including establishing digital camera quality assurance and camera calibration processes for USGS and ASPRS, led the development of USGS and ASPRS Lidar Data Quality Guidelines, the ASPRS in Situ Calibration Guidelines, and the DOI UAS Calibration Guidelines. Stensaas is currently the ASPRS Standard Committee Chair and has served three times as the ASPRS Primary Data Acquisition Division Director (PDAD). Stensaas is currently working on revising the ASPRS Ten-Year Remote Sensing Industry Forecast. He was also the USGS lead and co-chair of the Joint Agency Commercial Imagery Evaluation program for 18 years. Stensaas also served as chair of the Federal Inter-Agency Digital Imagery Working Group, the Chair of the Committee on Earth Observation (CEOS) Working Group on Calibration and Validation (and helped establish the Quality Assurance for Earth Observation Strategy for CEOS and the Group on Earth Observation. Stensaas was a member of the National Digital Orthoimagery Program and past chair of the Technical Management Subcommittee.

Stensaas has a BS in Mechanical Engineering from South Dakota State University and has been in Engineering and Information Technology post graduate programs at the University of Nebraska–Lincoln and Dakota State University.

Purpose: Started in 1992, the designation of Fellow is conferred on Society members who have been active for a total of at least ten years and who have performed exceptional service in advancing the science and use of the mapping sciences and related disciplines. It is awarded for professional excellence and for service to the Society.

Donor: ASPRS. The ASPRS Fellow Award includes a lapel pin and a certificate.

The Estes Memorial Teaching Award

2024 recipient: Dr. L. Monika Moskal

Dr. L. Monika Moskal is the recipient of the Estes Memorial Teaching Award to recognize her passion for teaching and training geospatial concepts, theory and applications; the excellent quality of her student mentorship; and her involvement of students in research on geospatial analysis and geovisualization of forest resources. Moskal brings an energy to the classroom, laboratory and field that is contagious.

Moskal earned a BS degree in Geography with Honors, from the University of Waterloo, an MS in Remote Sensing and GIS from the University of Calgary, and a PhD in Geography from the University of Kansas in 2005. Moskal began her teaching career in 2003 in the Department of Geography, Geology and Planning at Missouri State University. She moved to the University of Washington in 2006 as an Assistant Professor in the Department of Geography, attaining the rank of Associate Professor in 2013 and full Professor in 2020. She is the Director of the Precision Forestry Cooperative (2013-present) and the lead Principal Investigator (PI) of the Remote Sensing and Geospatial Analysis Laboratory (2006-present) at the University of Washington.

Moskal has developed several geospatial courses at UW including “Lidar Remote Sensing”, “Remote Sensing of Environment” and “Digital Earth” with average enrollments each year of approximately 50, 100 and 30 students, respectively. She also regularly co-teaches “Wildlife Conservation” in the Pacific Northwest Ecosystems and Environmental and Resource Assessment programs, and developed a workshop, “Impacts of Climate Change on the Pacific Northwest” held in 2019 and 2023.

Moskal’s research funding totals over $23.5M, serving as PI for over $7.9M of these externally-funded research projects. Throughout her career Moskal has mentored students at undergraduate, graduate and post-graduate levels in all aspects of research. For example, she obtained Research Experience for Undergraduates grants from the UW Stand Management Cooperative and National Science Foundation to support students working with airborne and terrestrial lidar to monitor and visualize Leaf Area Index changes in the forests of the Pacific Northwest. Since 2003, she has supervised nine Postdoctoral Fellows, served as Chair or Co-Chair for 19 MS and 15 PhD students, served on 36 graduate committees and supervised 27 undergraduate projects. Her students have explored research including thermal remote sensing of forests, NASA WetCarbon research, lidar-based forest moisture metrics, wetland change and policy patterns, monitoring the impacts of climate change on wetland dynamics, and many more. Notably, the majority of her 70+ peer-review journal publications are authored by students supported by her research grants.

In 2021, she was selected as a Fellow in the Wilburforce Leaders in Conservation Science Program, and in 2019, she received the UW School of Environmental and Forest Sciences Director’s Award for Service to the School. She was nominated twice (2009 and 2018) for the UW Marsha L. Landolt Distinguished Graduate Mentor Award and recognized in 2009 by UW for her Exemplary Contribution to the College in Faculty Teaching, College of Forest Resources. The same year she received the ASPRS Ford Bartlett Membership Award for her promotion of student membership in ASPRS. Her service to UW students includes Faculty Representative on the Graduate School Council since 2021, and since 2006, faculty advisor to the student UW Geospatial Club. Dr. Moskal has always been extremely active in professional societies, both national and international. Her mentorship extends to professional development of her students and she regularly uses her research funds to support their travel to conferences to present their joint research.

Purpose: To recognize individual achievement in the promotion of remote sensing and geographic information systems (GIS) technology and applications through educational efforts.

Donor: ASPRS with funding provided by the ASPRS Foundation and ASPRS. The Estes Memorial Teaching Award is made in honor of Professor John E. (“Jack”) Estes, teacher, mentor, scientist, and friend of ASPRS. The award consists of a presentation plaque and a cash award of $3,000.

ASPRS Photogrammetric Award (Fairchild)

2024 recipient: Dr. Jason Stoker

Dr. Jason Stoker is a United States Geological Survey (USGS) Physical Scientist for the National Geospatial Program. Dr. Stoker earned his Ph.D. in Geospatial Science and Engineering from South Dakota State University, and MS and BS degrees from Colorado State University in Geomatics and Natural Resources Management, respectively. He is currently the Elevation Science and Applications Lead for the National Geospatial Program and is the Federal Geospatial Data Committee National Geospatial Data Asset Data Manager for four national elevation theme datasets: lidar point cloud, 1 m digital elevation models (DEMs), 1/3rd arc-second DEMs, and 5 m Alaska DEMs. Stoker oversees strategic planning, development and coordination of the 3D Elevation Program (3DEP) and related data, tools, and services. Stoker provides technical expertise, prepares roadmaps and plans for elevation products and services, and helps determine the long-term vision for 3DEP products and services.

Stoker has worked at the USGS for over 21 years. Prior to his current position, Stoker spent twelve years leading the lidar research and development activities at USGS EROS Center in Sioux Falls, South Dakota. He was the founder of the USGS Center for Lidar Information Coordination and Knowledge. While working on his master's degree, Stoker spent three years working as a biologist for the United States Forest Service. In this role, Stoker performed geospatial analyses for research on historic fire regimes in the Colorado Front Range.

Stoker is a former Director of the Lidar Division of ASPRS and Past President of ASPRS. He has published widely on the accuracy, consistency, and application of three-dimensional topographic models including articles in *Remote Sensing of Environment* and *MDPI Remote Sensing*.

Purpose: The Photogrammetric Fairchild Award is designed to stimulate the development of the art of aerial photogrammetry in the United States. Practicability is the essence of the Award and is the basis for the review of all candidates.

Donor: ASPRS. The award consists of an engraved presentation plaque.

The ASPRS Outstanding Technical Achievement Award

2024 recipient: Dr. Gerald Mader

Dr. Gerald Mader received his Ph.D. in astronomy from the University of Maryland in 1975. He served as the Chief of the Geosciences Research Division at the National Geodetic Survey (NGS), National Oceanic and Atmospheric Administration (NOAA) in Silver Spring, Maryland. His research focused on improving accuracy using global navigation satellite system (GNSS) data. Mader receives this award in recognition of his leadership in creating and implementing the Online Positioning User Service (OPUS) at NOAA/NGS. OPUS is a free, web-based tool providing GPS/GNSS users rapid access to the National Spatial Reference System (NSRS). Three-dimensional, centimeter-level accuracies are provided within minutes of data submittal to OPUS. OPUS made a major and immediate impact on the surveying, mapping, and remote sensing communities when first introduced and remains a widely used and popular service for federal, state, local, and commercial professionals. The consistent geodetic control provided by OPUS is the foundation for georeferencing a wide variety of essential mapping, surveying and engineering applications. OPUS also allows users to preserve their results in an on-line database where they can be shared and preserved for temporal monitoring. Since Mader introduced OPUS in 2000, many millions of positions have been and continue to be computed for many thousands of users; a clear indication of this important tool's impact.

Mader was a cofounder of the International GNSS Service and developer of the NGS antenna calibration program. He wrote software to support precise static and kinematic positioning. Mader is also coauthor of the original Receiver Independent Exchange (RINEX) format, which is a data interchange format that is the industry standard for raw GNSS data.

Purpose: This grant is designed to reward the developer[s] of a specific breakthrough technology that causes quantum advances in the practice of photogrammetry, remote sensing or geographic information systems in the United States.

Donor: In 2011, the ASPRS Foundation received a generous individual donation from Lifetime Achievement Awardee and ASPRS Fellow Clifford W. Greve to endow a new Outstanding Technical Achievement Award. The Award was first given in 2012 and is fully endowed at the $8,000 level. This Award consists of a silver presentation plaque mounted on a wood panel and a check for $8,000.

The ASPRS Lifetime Achievement Award

2024 recipient: Dr. Charles Toth

Dr. Charles Toth is a research professor in the Department of Civil, Environmental, and Geodetic Engineering at The Ohio State University, where he serves as co-director of the Satellite Positioning and Inertial Navigation (SPIN) Laboratory. Toth was the key architect of the concept development and implementation of the first mobile mapping system (MMS), one of the first civilian applications of GPS. He is considered one of the founding fathers of MMS and is recognized worldwide for his contributions for advancing MMS technology and its applications. Later, he led the OSU team in the groundbreaking project Airborne Integrated Mapping System (AIMS™), which delivered a first in the world fully digital directly georeferenced high-accuracy airborne mapping system prototype based on tight integration of GPS and inertial navigation unit (IMU) data. Subsequently, Toth led significant research effort on direct georeferencing of remote sensing platforms, introducing GPS/IMU based sensor orientation into the mapping community, and is generally credited with coining the terms "direct and indirect georeferencing."

Toth is an ASPRS Fellow, a Fellow of the International Society of Photogrammetry and Remote Sensing (ISPRS), and a Fellow of the Institute of Navigation (ION). He received an *Honorary Doctorate* from the Budapest University of Technology and Economics and was the recipient of the ASPRS Photogrammetric Award (Fairchild) award in 2009. He is a Past President of ASPRS and has a long record of serving both ASPRS and ISPRS. Toth served as Director of the Photogrammetric Applications Division and was active in the leadership of the Eastern Great Lakes Region. He served ISPRS as Vice President and has previously served as Chair and Co-chair of various ISPRS working groups.

The ASPRS Lifetime Achievement Award (formerly the Honorary Lifetime Achievement Award and the Honorary Member Award) is the highest award an ASPRS member can receive, and there are only 25 living Lifetime Achievement Awardees of the Society at any given time. Candidates are chosen by a Nominating Committee made up of the past five recipients of the award and chaired by the most recent recipient.

Purpose: Initiated in 1937, this life-time award is given in recognition of individuals who have rendered distinguished service to ASPRS and/or who have attained distinction in advancing the science and use of the geospatial information sciences. It is awarded for professional excellence and for at least 20 years of service to ASPRS and consists of a plaque and a certificate.

Donor: ASPRS

The International Educational Literature Award (IELA)

Not awarded this year

Purpose: to improve the quantity and quality of the literature in the library of the recipient Institution that deals with the mapping sciences (i.e., photogrammetry, remote sensing, GIS, and related disciplines).

Donor: ASPRS. The Award consists of the following: A set of manuals published by ASPRS; A five-year e-subscription to *Photogrammetric Engineering & Remote Sensing*; Proceedings of the annual conference for a five-year period.

George E. Brown, Jr. Congressional Honor Award

Not awarded this year

Purpose: This award was established in honor of Congressman George E. Brown, Jr., and the contributions he made to advance the benefits of imagery and geospatial information to society. The award is given periodically to recognize members of the U.S. Congress whose leadership and personal efforts have advanced the science, engineering, application, education, and commerce of imaging and geospatial information.

Donor: ASPRS

ASPRS Presidential Citations

Danielle Blanch
For support of the Certification program

Yuki Day
For support of headquarters operations

Ken Meme
For supporting ASPRS involvement over the past 23 years at both the Regional and National level

Ben Wilkinson
For supporting the society through meritorious service in preparing Operating Procedures for the Photogrammetric Applications Division of ASPRS

Purpose: First awarded in 1992, Presidential Citations are presented by the ASPRS President to members of ASPRS and other societies, family members, and friends in recognition of special, personal, and meritorious contributions to the operation or advancement of the Society and its interests during the presidential year.

Donor: ASPRS. The Presidential Citation is a certificate.

(L-R) Lorraine Amenda, Yuki Day, Brian Young accepting on behalf of Ken Meme, and Ben Wilkinson.

ASPRS Outstanding Service Award

Oscar Duran
For leading reorganization of the Student Advisory Council.

Qassim Abdullah, Colin Lee, Riadh Munjy, Josh Nimetz, Michael Zoltek
For serving on the Standards Revision Working Group that developed the ASPRS Positional Accuracy Standard for Digital Geospatial Data, Edition 2, V1 - August 2023

David Day, Nora Csanyi May, Srini Dharmapuri, Sagar Deshpande, Jim Gillis, Jacob Lopez
For leading a Positional Accuracy Standards Addenda Working Group.

(L-R) Lorraine Amenda and Brian Young accepting on behalf of Oscar Duran.

(L-R) Lorraine Amenda, Qassim Abdullah, Michael Zoltek, Colin Lee, and Josh Nimetz.

(L-R) Lorraine Amenda, Nora May, David Day, Srini Dharmapuri, and Jim Gillis.

ASPRS Outstanding Service Award (continued)

Matt Bethel, Maurice Elliot, John Erickson, Martin Flood, Jamie Gillis*, Ayman Habib, Azar Ibrahim, Kyle Ince*, Jeff Irwin*, Claire Kiedrowski, David Kuxhausen*, Leo Z. Liu, Charles Mondello, Mohamed Mostafa, Christopher E. Parrish, Thomas Prescott, Yuri Raizman, Harold Rempel, Bahram Salehi, Thom S. Salter, Ajit Sampath, Ethan Schreuder, Clay Smith, Ravi Soneja, Manya Waggoner, Michael Zarlengo*

For serving on a Positional Accuracy Standards Addenda Working Group

*Note: Addenda Working Group Awardees recognized in 2023.

Front row: (L-R) Mohamed Mostafa, Anthony Garetto accepting on behalf of Yuri Raizman, Matt Bethel, Lorraine Amenda, Claire Kiedrowski, Clay Smith, Bahram Salehi, and Qassim Abdullah accepting on behalf of Azar Ibrahim.
Back row: (L-R) Leo Liu, Ajit Sampath, Martin Flood, Ravi Soneja, Chris Parrish, Harold Rempel, Ethan Schreuder

Purpose: Established in 1991, The Outstanding Service Award is given in recognition of outstanding and unusual efforts in helping ASPRS develop and carry out its program over a sustained period. Recipients have performed outstanding service at the chapter, regional, or national level. Awardees' service includes any activities, including professional, that have helped the Society achieve its goals and objectives.

Donor: ASPRS. The Outstanding Service Award consists of a plaque or certificate.

Region Awards

Region of the Year

1st Place: **Pacific Southwest Region**
2nd Place: **Florida Region**
3rd Place: **Rocky Mountain Region**
Honorable Mention: **Gulf South Region**

(L-R) Lorraine Amenda, Eric Albanese, Rebecca Morton, Alan Mikuni, and Greg Saunders.

Region Community Page of the Year

1st Place: **Gulf South Region**
2nd Place: **Rocky Mountain Region**
3rd Place: **Pacific Southwest Region**
Honorable Mention: **Northeastern Region**

(L-R) Lorraine Amenda and Rebecca Capps.

Roger Hoffer Membership Award

Honorable Mention:
Balaji Ramachandran
Karen Schuckman

(L-R) Lorraine Amenda and Karen Schuckman.

Purpose: First awarded in 1968 as the ASPRS Ford Bartlett Membership Award (which was originally sponsored by the firm of Lockwood, Kessler, and Bartlett, Inc.) to honor members for actively promoting membership in ASPRS. This award now marks the exceptional efforts of ASPRS Past President Roger Hoffer in managing the Membership Committee and recruiting hundreds of student members.

Donor: ASPRS. A member is eligible to receive the Award after sponsoring ten or more members in one year. Each recipient receives a hand-engrossed certificate and a one-year membership in the Society. An Honorable Mention is awarded to those who sponsor at least five new members.

OUTSTANDING PAPER AWARDS

The Esri Award for Best Scientific Paper in GIS

1st Place

Linfeng Wu, Linfeng Wang, Huiqing Wang for "A Lightweight Conditional Convolutional Neural Network for Hyperspectral Image Classification", *PE&RS*, 89(7): 413-423.

2nd Place

Daiwei Zhang, Bo Xu, Han Hu, Qing Zhu, Qiang Wang, Xuming Ge, Min Chen, Yan Zhou for "Spherical Hough Transform for Robust Line Detection Toward a 2D–3D Integrated Mobile Mapping System." *PE&RS*, 89(5): 311-320.

3rd Place

Yanis Marchand, Laurent Caraffa, Raphael Sulzer, Emmanuel Clédat, and Bruno Vallet for "Evaluating Surface Mesh Reconstruction Using Real Data." *PE&RS*, 89(10): 625–638.

Purpose: Established in 1991, the fully endowed Esri Award honors individuals who publish papers of scientific merit that advance our knowledge about GIS technology.

Donor: Esri, Inc. through the ASPRS Foundation. The First-Place award includes a cash award of $1,500 and a certificate; Second Place is a cash award of $900 and a certificate; Third Place is a cash award of $600 and a certificate.

John I. Davidson President's Award for Practical Papers

1st Place

Yunus Kaya, Halil İbrahim Şenol, Abdurahman Yasin Yiğit, Murat Yakar for "Car Detection from Very High-Resolution UAV Images Using Deep Learning Algorithms." *PE&RS* 89(2): 117-123.

2nd Place

Jiaxin Xu, Qiao Zhang, Yu Liu, Mengting Zheng for "Small Object Detection in Remote Sensing Images Based on Window Self-Attention Mechanism." *PE&RS*, 89(8): 489-497.

3rd Place

Yueming Sun, Jinlong Chen, XiaoHuang, Hongsheng Zhang for "Multi-Level Perceptual Network for Urban Building Extraction from High-Resolution Remote Sensing Images." *PE&RS*, 89(7): 427-434.

Purpose: The John I. Davidson President's Award for Practical Papers was established in 1979 to encourage and commend individuals who publish papers of practical or applied value in *PE&RS*.

Donor: The ASPRS Foundation in memory of ASPRS Past President John I. Davidson. The First-Place award includes a cash award of $1,000 and a certificate; Second Place is a cash award of $600 and a certificate; Third Place is a cash award of $400 and a certificate.

Talbert Abrams Award

Grand Award

Forrest Corcoran, Christopher E. Parrish for "DORSL-FIN: A Self-supervised Neural Network for Recovering Missing Bathymetry from ICESat-2." *PE&RS* 89(9): 561-575.

(L-R) Bandana Kar, Forrest Corcoran, and Christopher E. Parrish

Purpose: The Talbert Abrams Award was established in 1945 to encourage the authorship and recording of current, historical, engineering, and scientific developments in photogrammetry. The Award is determined from papers published in the *Photogrammetric Engineering and Remote Sensing* (*PE&RS*) journal.

Donor: The ASPRS Foundation. The award consists of a certificate and a check for $4,000 for the Grand Award, and a certificate for First and Second Honorable Mentions.

SCHOLARSHIPS

Robert E. Altenhofen Memorial Scholarship

2024 recipient: Hamdy Elsayed

Hamdy Elsayed has recently completed a Ph.D. in Geomatics Engineering from Toronto Metropolitan University and is working for Teledyne Geospatial. He had previously received an M.Sc. (with Distinction) in Information Technology Business Management from the British University in Dubai and B.Sc. (with Honors) in Electrical Engineering from Alexandria University. His research has focused on two areas: dynamic lidar mapping and indoor mapping. Esayed's research in dynamic lidar mapping focused on capturing data in motion to expand applications in urban planning, environmental monitoring, and infrastructure management. His research in indoor mapping sought to identify cost-effective and efficient solutions, particularly in GNSS-denied environments. Through his research Elsayed hopes to transform the way geospatial professionals collect and utilize data, making it more accessible and versatile.

Purpose: First given in 1986, the Robert E. Altenhofen Memorial Scholarship is intended to encourage and commend college students who display exceptional interest and ability in the theoretical aspects of photogrammetry.

Donor: The ASPRS Foundation. This award was originally established by Mrs. Helen Altenhofen as a memorial to her husband, Robert E. Altenhofen, past president of ASPRS. He was an outstanding practitioner of photogrammetry and made notable contributions to mathematical aspects of the science. The Altenhofen Scholarship consists of a certificate, a check for $2,000, and a one-year membership renewal in the Society.

(L-R) Bandana Kar and Hamdy Elsayed

Abraham Anson Memorial Scholarship

2024 recipient: Susanna Eng

Susanna Eng is completing a Bachelor of Science in Geospatial Engineering at Cal Poly Pomona with a minor in computer information science. Eng aspires to become a systems engineer specializing in Global Navigation Satellite Systems to improve national defense within geospatial-intelligence. She aims to use her background in technology to better create geodetic infrastructure allowing for more accurate measurements and stronger network signals. Eng has held an internship with Caltrans District 7 focusing on georeferencing utility maps, drafting network baselines, updating benchmark recovery notes, and creating postmile shapefiles. She has also worked on campus in information technology support and served as a teaching assistant for multiple sections of a computing course. Eng has presented at the Pacific Southwest Symposium, an annual engineering student conference, on the usage of implementing digital twins for improving water leak detection to improve hydraulic infrastructure.

Purpose: To encourage students who have an exceptional interest in pursuing scientific research or education in geospatial science or technology related to photogrammetry, remote sensing, surveying, and mapping to enter a professional field where they can use the knowledge of their discipline to excel in their profession.

Donor: This award is presented by the ASPRS Foundation from funds donated by the Anson bequest and contributions from the Society and the Potomac Region as a tribute to Abe Anson's many contributions to the field of photogrammetry, remote sensing, and long, dedicated service to the Society. The award consists of a certificate, a check for $2,000, and a one-year membership renewal in the Society.

John O. Behrens Institute for Land Information (ILI) Memorial Scholarship

2024 recipient: Omar Madrigal

Omar Madrigal is a senior studying civil engineering with a geospatial option at California State Polytechnic University, Pomona, CA. Madrigal is described as a "remarkable student and esteemed amongst his peers" by his references. Madrigal has completed highly relevant coursework and achieved an exceptional GPA throughout his schooling. He has completed numerous internships including serving as an assistant surveyor at a private surveying firm in Pomona, CA where he designed topographic maps from a variety of surveyed and report data. He also interned as a surveyor technician with a Brea, CA land engineering firm where he staked property boundaries as well as assisted surveyors during residential and commercial property efforts. Madrigal aspires to attain his Professional Land Surveyor and Professional Engineer licenses with the ambition to build and own a surveying firm. These combined factors demonstrate strong evidence that he will use the knowledge of the discipline to excel in his profession, which is befitting of the spirit and purpose of the John O. Behrens Institute for Land Information (ILI) Memorial Scholarship.

Purpose: To encourage students who have an exceptional interest in pursuing scientific research or education in geospatial science or technology or land information systems/records to enter a professional field where they can use the knowledge of this discipline to excel in their profession.

Donor: This award is presented by the ASPRS Foundation from funds donated by the (now dissolved) Institute for Land Information (ILI). The John O. Behrens ILI Memorial Scholarship was established by the ILI as a tribute to the many contributions of Mr. John O. Behrens to the field of geographic and land related information and technology. Mr. Behrens was a founder of the ILI and the author of many articles about the value of spatial information, land assessment and taxation, and land information policy. The Award consists of a certificate, a check for $2,000, and a one-year membership renewal in the Society.

(L-R) Bandana Kar and Omar Madrigal

Robert N. Colwell Memorial Fellowship

2024 recipient: Mohammad Abdul Qadir Khan (Abdul Qadir)

Abdul Qadir completed his PhD in Fall 2023 from the University of Maryland, College Park. He had previously earned an MS in Geospatial Data Science in 2020 (University of Delaware) and a BTech in Physical Sciences in 2012 (Indian Institute of Space Science and Technology). Qadir's expertise lies in the use of multi-scalar time series satellite images, machine-learning algorithms, and GIS tools within the area of agriculture and food security. His doctoral research focused on crop mapping using Earth observations, specifically in regions where field surveys are restricted. He developed an innovative radar-based model to map crops throughout Ukraine to assist food security initiatives of the Ukrainian Ministry of Agriculture and other international organizations operating in Ukraine. Qadir has received numerous scholarships and awards including the ASPRS Ta Liang Memorial Award and the Future Investigators in NASA Earth and Space Science and Technology (FINESST) grant. The FINESST grant enabled him to study the impact of climate change on agriculture in northern climates. Qadir is currently working on expanding his model to other crops in Ukraine as well as other regions in the world.

Purpose: Established in 2006 to encourage and commend college/university graduate students or post-doctoral researchers who display exceptional interest, desire, ability, and aptitude in the field of remote sensing or other related geospatial information technologies, and who have a special interest in developing practical uses of these technologies.

Donor: This award is presented by the ASPRS Foundation, from funds donated by students, associates, colleagues, and friends of Robert N. Colwell. Over the course of more than a half century, Dr. Robert N. Colwell developed a reputation as one of the world's most respected leaders in remote sensing, a field that he stewarded from the interpretation of aerial photographs during World War II, to the advanced acquisition and analysis of many types of geospatial data from military and civilian satellite platforms. His career included nearly 40 years of teaching and research at the University of California, Berkeley, a distinguished record of military service reaching the rank of Rear Admiral, and prominent roles in private industry and as a consultant for many U.S. and international agencies. Among his many accolades, Dr. Colwell had the distinction of being one of the 25 Honorary Members of ASPRS. The Award consists of a certificate, a check for $8,000, and a one-year membership renewal in the Society.

William A. Fischer Memorial Scholarship

2024 recipient: Jeng Hann Chong

Jeng Hann Chong is pursuing a Ph.D. in geodesy from the University of New Mexico. He has previously earned an MS in geophysics from California State University Northridge (2021) and a BS in geology from the University of Maryland – College Park (2019). Chong has received multiple awards including a Future Investigators in NASA Earth and Space Science and Technology (FINESST) grant. His primary research focus involves using satellite radar images and modeling to study the complex tectonic regimes and deformation in Myanmar in order to understand the driving mechanisms. Chong is also engaged in a second project building from his master's research that studies mass-wasting events such as post-fire debris flows. Chong intends to pursue a career that will allow him to use remote sensing to study tectonic deformation and natural hazards in slowly deforming regions that could potentially cause even greater damage to unprepared communities. He is driven by personal experience during an earthquake event in Malaysia and seeks to provide science education to those lacking adequate natural hazards awareness.

Purpose: The William A. Fischer Scholarship facilitates graduate studies and career goals of a worthy student adjudged to address new and innovative uses of remote sensing data and techniques that relate to the natural, cultural, or agricultural resources of the Earth. It was established in 1984.

Donor: The ASPRS Foundation through individual and corporate contributions in memory of William A. Fischer. The William A. Fischer Memorial Scholarship consists of a certificate, a check for $2,000, and a one-year membership renewal in the Society.

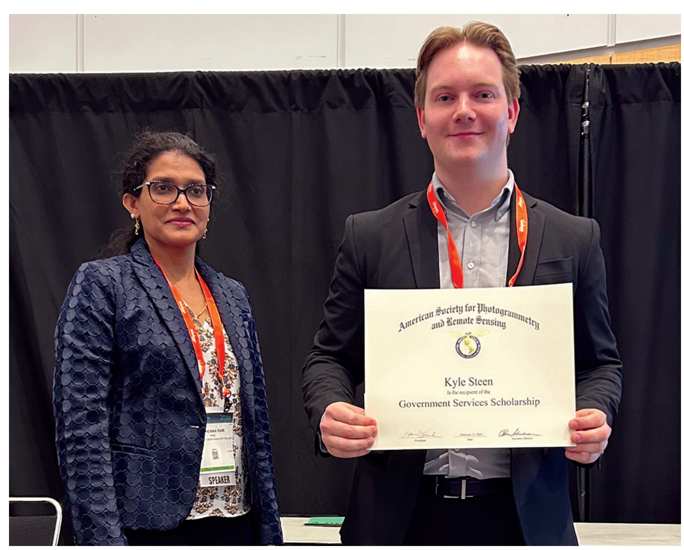
Government Services Scholarship

2024 recipient: Kyle Steen

Kyle Steen is currently pursuing a master's degree in geography from the University of Georgia (UGA) after completing BS in ecology, with a minor in Geography and a Certificate in GIS from UGA in 2021. Steen enrolled in the School of Ecology at UGA initially to learn about ecological processes and phenomena, but his interest in GIS led to summer employment with the State Botanical Garden of Georgia in Athens, Georgia where he mapped individual gardens, monuments, and utility lines. Upon completing his BS he worked with the Okefenokee Water Resources team as part of the NASA DEVELOP Program and during the summer of 2022, Steen collaborated with partners at Yellowstone National Park to identify aspen (*Populus tremuloides*) stands within the park using time series analysis stretching back to 1986. During his MS program Steen has acquired a FAA Part 107 UAS drone pilot's license, which he applied during summer work with the United States Department of Agriculture – Agricultural Research Service in Tion, GA. After graduating, Steen seeks to move into employment with the government sector to use the geospatial skills he has gained to solve complex challenges.

Purpose: The Government Services Scholarship encourages upper-division undergraduate and graduate-level college students to pursue a course of study in photogrammetry and related topics leading to a career in the geospatial mapping profession in the government sector (federal, state, or local) within the United States. The Award also encourages geospatial professionals already in government service to pursue advanced degrees and provides a preference to U.S. veterans.

Donor: The ASPRS Foundation through the support of an anonymous donor who is a long-time supporter of ASPRS and the ASPRS Foundation. The Government Services Scholarship consists of a certificate, a check for $7000, and a one-year membership renewal in the Society.



(L-R) Bandana Kar and Kyle Steen.

Francis H. Moffitt Memorial Scholarship

2024 recipient: Elias Fierro

Elias Fierro is an undergraduate attending California State University, Fresno majoring in Geomatics Engineering and expects to graduate in 2025. He has been working for Benchmark Engineering in Modesto, CA for the past three years and has progressed from technician to Party Chief. He has acquired his certificate as a Land Surveyor in Training. Fierro's short-term goal is to obtain an FAA Part 107 UAS drone pilot's license and eventually to obtain a license as a Professional Land Surveyor. His career goal is to work in the geospatial industry as a Land Surveyor using modern technology in photogrammetry and remote sensing. Fierro is very active in extracurricular activities and is serving as President of the Student Association of Geomatics Engineering (SAGE), which encourages students through career and club fairs. He served as co-chair of the 63rd Annual Geomatics Conference at Fresno State and will be chair next year. The annual conferences allow students to network with working professionals for their experience and perspective and to raise funds for SAGE.

Purpose: The award was first presented in 2008 with the purpose of encouraging upper-division, undergraduate-level, and graduate-level college students to pursue a course of study in surveying and photogrammetry leading to a career in the geospatial mapping profession.

Donor: The ASPRS Foundation from funds donated to the Foundation from former students, associates, colleagues, and friends of Francis Moffitt. The award consists of a certificate, a check for $9,000, and a one-year membership renewal in the Society.

(L-R) Bandana Kar and Yushin Ahn accepting on behalf of Elias Fierro.

The Kenneth J. Osborn Memorial Scholarship

2024 recipient: Oren Nardi

Mr. Oren Nardi is pursuing a Bachelor of Science degree in Environmental Science and Management, concentrating on Geospatial Science with a Minor in Forestry from Cal Poly Humboldt. Nardi anticipates graduating in December of 2024. Following his undergraduate degree program, he plans to continue his education through graduate studies at the University of California at Davis. His long-term professional career goal in the geospatial field is to spearhead commercial-grade UAS applications into solving real-world questions such as monitoring landscape-based vegetation treatments. Nardi exemplifies the Osborn qualities of communication and collaboration through participation in activities within the Cal Poly Humboldt campus community by serving in key roles with university partners, such as, the Open Forest Observatory, Cultural Fire Management Council, and with the College of the Redwoods.

Purpose: to encourage and commend college students who display exceptional interest, desire, ability, and aptitude to enter the profession of surveying, mapping, photogrammetry, or geospatial information and technology. In addition, the Award recognizes students who excel at an aspect of the profession that Ken demonstrated so very well, that of communications and collaboration.

Donor: The ASPRS Foundation from funds donated by the friends and colleagues of Kenneth J. Osborn. Recognized nationally and internationally, Ken was an outstanding practitioner of surveying, mapping, photogrammetry, and geospatial information and technology, and a great friend of the Society. As a professional cartographer with the U.S. Geological Survey, Ken made significant contributions to these fields. The award was first offered in 2005. The Award consists of a certification, a check for $2,000, and a one-year membership renewal in the Society.

Ta Liang Memorial Award

2024 recipient: Sarah Esenther

Sarah Esenther is a geoscience doctoral student at Brown University researching Arctic remote sensing hydrology. She had previously completed a BS in civil/environmental engineering at the University of Massachusetts Amherst and a Master of Public Health in Environmental Health Science from Yale University. Esenther aims to advance the use of remote sensing technologies in polar hydrology applications to improve modeling and projection of climate change impacts. In her first doctoral paper, Esenther used remotely sensed albedo, snow cover, and precipitation to supplement field measurements of meteorological variables from a watershed in Northwest Greenland in order to identify drivers of variability in total meltwater runoff. Her current research is focused on developing a machine learning tool that uses WorldView, Sentinel-2, and Landsat imagery to map supraglacial streams and lakes over the Greenland Ice Sheet. Throughout her graduate students, Esenther has mentored undergraduate and high school students, introducing them to public remote sensing data and open-source software. Esenther will use the Ta Liang award to fund travel for herself and two other graduate students to support coordination of a new project exploring the role of surface water on ice shelf stability.

Purpose: To facilitate research-related travel by outstanding graduate students in remote sensing, including field investigations, agency visits, participation in conferences, or other travel that enhances or facilitates graduate research.

Donor: Individual and corporate contributions to the ASPRS Foundation in memory of Ta Liang, a skilled civil engineer, an excellent teacher, and one of the world's foremost air photo interpreters, the award consists of a certificate, a check for $2,000 grant, and a one-year membership renewal in the Society.

Paul R. Wolf Memorial Scholarship

2024 Recipient: David Abiola

David Abiola is presented the Paul R. Wolf Memorial Scholarship in recognition of his outstanding academic credentials and his plans and enthusiasm to become an education and research professional in Surveying, Mapping, Photogrammetry, and related fields. Abiola is currently a doctoral candidate in Civil Engineering with an emphasis in Geomatics at Oregon State University with a projected graduation date of September 2026. Abiola has demonstrated a continued interest, dedication, enthusiasm, passion, and aptitude to become an education professional as exemplified by his outstanding work as a teaching assistant. He wants to grow his skill set and continually learn new technologies in the geomatics field. Abiola's career goal is to become a recognized researcher, problem-solver, and educator.

Purpose: To encourage and commend college students who display exceptional interest, desire, ability, and aptitude to enter the profession of teaching surveying, mapping, or photogrammetry.

Donor: the ASPRS Foundation from funds donated by the friends and colleagues of Paul R. Wolf. Recognized nationally and internationally, Dr. Wolf was an outstanding educator and practitioner of surveying, mapping, and photogrammetry and a great friend of the Society. As author, teacher, and mentor, Dr. Wolf made significant educational and academic contributions to these fields. The award was inaugurated in 2003 and includes a certificate, a check for $5,000, and a one-year membership renewal in the Society.

(L-R) Bandana Kar and David Abiola

ANNUAL BUSINESS MEETING AND INSTALLATION OF OFFICERS

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Youssef Kaddoura, *Early Career Professional Council*
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Aparajithan Sampath, *Lidar Division*
Ben Wilkinson, *Photogrammetric Applications Division*
Jacob Lopez, *UAS Division*

Installation of New Council Chairs

David Day, *Committee Chairs Council*
Greg Stamnes, *Early Career Professional Council*
Oscar Duran, *Student Advisory Council*
Paul Badr, *Sustaining Members Council*

Installation of New Division Directors

Jin Lee, *GIS Division*
Matt Bethel, *Lidar Division*
Hank Theiss, *Photogrammetric Applications Division*
Bahram Salehi, *UAS Division*

Installation of New Division Assistant Directors

Michael Baranowski, *GIS Division*
Rebecca Capps, *UAS Division*
Jae Sung Kim, *Photogrammetric Applications Division*
Nora May, *Lidar Division*

Recognition of Retiring Past-President

Christopher Parrish, *Immediate Past President*

(L-R) Lorraine Amenda, David Day, and Paul Badr.

(L-R) Lorraine Amenda, Matt Bethel, Bahram Salehi, and Hank Theiss.

(L-R) Lorraine Amenda, Michael Baranowski, Rebecca Capps, Jae Sung Kim, and Nora May.

Installation of Officers

Alvin Karlin, *Vice-President*

Amr Abd-Elrahman, *President-Elect*

Bandana Kar, *President*

Presentation of Birdseye Citation and President's Key to Retiring President

Lorraine Amenda, Immediate Past-President

(L-R) Bandana Kar and Lorraine Amenda.

Purpose: The Col. Claude H. Birdseye President's Citation was established in 1965 as a tribute to one of the founders and the first president of the Society. Each year at the Annual Convention it is conferred on the outgoing president in recognition of her/his contributions to the Society.

Donor: ASPRS. The Birdseye Citation carries with it a gold Past President's Key, and a certificate. The retiring President will also receive the Presidential Gavel mounted on a walnut plaque.

(L-R) Lorraine Amenda and Alvin Karlin

(L-R) Lorraine Amenda and Amr Abd-Elrahman

(L-R) Lorraine Amenda and Bandana Kar

Using Improved YOLOv5 and SegFormer to Extract Tailings Ponds from Multi-Source Data

Zhenhui Sun, Ying Xu, Dongchuan Wang, Qingyan Meng, and Yunxiao Sun

Abstract

This paper proposes a framework that combines the improved "You Only Look Once" version 5 (YOLOv5) and SegFormer to extract tailings ponds from multi-source data. Points of interest (POIs) are crawled to capture potential tailings pond regions . Jeffries–Matusita distance is used to evaluate the optimal band combination. The improved YOLOv5 replaces the backbone with the PoolFormer to form a PoolFormer backbone. The neck introduces the CARAFE operator to form a CARAFE feature pyramid network neck (CRF-FPN). The head is substituted with an efficiency decoupled head. POIs and classification data optimize improved YOLOv5 results. After that, the SegFormer is used to delineate the boundaries of tailings ponds. Experimental results demonstrate that the mean average precision of the improved YOLOv5s has increased by 2.78% compared to the YOLOv5s, achieving 91.18%. The SegFormer achieves an intersection over union of 88.76% and an accuracy of 94.28%.

Introduction

A tailings pond is a facility used for the storage of waste from metal and nonmetal mines, in which the ore is sorted and the resulting tailings are discharged (Che *et al.* 2018). These ponds contain a complex composition of harmful, dangerous, and radioactive slag or tailings water, making them a potential high-risk hazard source. Accidents in tailings ponds can result in severe damage to the surrounding environment, significant loss of life and property, and detrimental effects on local economic development and social stability (Morgan *et al.* 2016). Due to factors such as mineral distribution and terrain, tailings ponds are often located in remote mountainous areas or ecologically sensitive areas. Additionally, many enterprises ignore their storage and disposal because of cost control, leading to major accidents (Van Niekerk and Viljoen 2005). This presents significant challenges to the supervision and emergency management of tailings ponds. Traditional supervision methods rely on manual statistics and on-site visits, which are inadequate for the oversight of large-scale and high-efficiency tailings ponds. However, the emergence of remote sensing and artificial intelligence technology has greatly improved the accuracy, automation, and efficiency of remote sensing target recognition. Therefore, the application of these advanced technologies to the extraction of tailings ponds is of paramount importance for the safety supervision and environmental protection of these facilities.

Remote sensing technology has emerged as an important means for detecting tailings ponds, offering benefits such as wide observation range, abundant information, rapid data acquisition, and frequent updates. Numerous methods for tailings pond detection have been proposed, taking into account spectral, texture, shape characteristic, and application data. Traditional approaches can be classified into three types: (1) the visual interpretation method, (2) the index construction method, and (3) the classification identification method. For the visual interpretation method, Farrand and Harsanyi (1997) used a constrained energy minimization technique to map the distribution of mine tailings in the Coeur d'Alene River Valley. Xiao *et al.* (2012) used visual interpretation signs to identify and extract tailings pond information through human–computer interaction. For the index construction method, Ma *et al.* (2018) used Landsat 8 Operational Land Imager (OLI) data and a newly constructed ultra-low-grade iron index along with temperature information to accurately identify tailings. Hao *et al.* (2019) introduced a tailings extraction model using various tailings indices based on iron-bearing minerals. For the classification identification method, Wu (2022) designed a support vector machine method for automatic detection of tailings ponds. Yu *et al.* (2022) used an object-oriented and random forest method for tailings pool identification.

The integration of deep learning technology with remote sensing has led to the exploration of tailings pond identification methods based on deep learning. To effectively and efficiently extract tailings ponds, a target detection method based on the single-shot multibox detector deep learning technique was developed (Li *et al.* 2020). Yan *et al.* (2021) devised an improved method based on the Faster R-CNN target detection model, incorporating attention mechanism and feature pyramid networks (FPNs) for tailings pond identification. Lyu *et al.* (2021) proposed a method by combining "*You Only Look Once*" version 4 (YOLOv4) and the random forest algorithm to extract boundary information of tailings ponds. Sun *et al.* (2023) improved YOLOv5 by introducing the Swin Transformer and fusion block in Damo-YOLO to improve the accuracy of detecting tailings ponds.

YOLO is a popular deep learning framework that is widely used. As an outstanding representative of the YOLO family, YOLOv5 has high detection accuracy, fast inference speed, and small-weight files. It contains three parts: the backbone for feature extraction, the neck for feature fusion, and the head for target detection. Although YOLOv5 has excellent performance, the detection of tailings ponds continues to be challenging because of complex background environments, distinct variations in pond characteristics, and nonuniform and sparse spatial distributions. Therefore, an improved YOLOv5 for tailings pond extraction needs to be designed. SegFormer stands out as a straightforward, efficient, and potent semantic segmentation framework that seamlessly merges the transformer architecture with a nimble multi-layer perceptual (MLP) decoder (Xie *et al.* 2021). It follows the established encoder–decoder structure, in which the encoder excels at producing multi-scale and multi-level features. The decoder consists only of MLP layers and incorporates multi-level features. SegFormer is suitable for identifying the extent of tailings ponds during emergencies.

In summary, extensive research has delved into the identification of tailings ponds, with their distinct variations in hue, shape, and size posing persistent challenges. Considering the possible emergency demand

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Contributed by Prasad S. Thenkabail, September 27, 2023 (sent for review October 16, 2023; reviewed by Yong Wang, Itiya Aneece).

Photogrammetric Engineering & Remote Sensing
Vol. 90, No. 4, April 2024, pp. 223–231.
0099-1112/22/223–231

doi: 10.14358/PERS.23-00066R2

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Founded in 1934, the American Society for Photogrammetry and Remote Sensing (ASPRS) is a scientific association serving thousands of professional members around the world. Our mission is to advance knowledge and improve understanding of mapping sciences to promote the responsible applications of photogrammetry, remote sensing, geographic information systems (GIS) and supporting technologies.

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GDP Spatialization in City of Zhengzhou Based on NPP/VIIRS Night-time Light and Socioeconomic Statistical Data Using Machine Learning

Inam Ullah, Weidong Li, Fanqian Meng, Muhammad Imran Nadeem, and Kanwal Ahmed

Abstract

This article introduces a comprehensive methodology for mapping and assessing the urban built-up areas and establishing a spatial gross domestic product (GDP) model for Zhengzhou using night-time light (NTL) data, alongside socioeconomic statistical data from 2012 to 2017. Two supervised sorting algorithms, namely the support vector machine (SVM) algorithm and the deep learning (DL) algorithm, which includes the U-Net and fully convolutional neural (FCN) network models, are proposed for urban built-up area identification and image classification. Comparisons with Municipal Bureau of Statistics data highlight the U-Net neural network model exhibits superior accuracy, especially in areas with diverse characteristics. For each year from 2012 to 2017, a spatial GDP model was developed based on Zhengzhou's urban GDP and U-Net sorted images. This research provides valuable insights into urban development and economic assessment for the city.

Introduction

This study integrates gross domestic product (GDP) data, exploring the relationship between urban areas and GDP changes, while presenting these data spatially. Changes in GDP are intrinsically linked to population dynamics and financial transformations within urban centers. GDP serves as an indispensable gauge of financial advancement and resource allocation (Wang *et al.* 2006; Henderson *et al.* 2012). The precise spatial distribution of GDP plays a pivotal role in depicting the level of economic growth, the configuration of business activities, local economic structures, and the developmental trajectory of regions or states (Zhao, Liu *et al.* 2017). However, conventional GDP data are typically reported in administrative units, failing to capture the spatial disparities within these regions (Wu *et al.* 2013). To address this limitation, a study on spatializing GDP was conducted to map administrative units' GDP onto a conventional grid (Zhao, Du *et al.* 2017; Cao *et al.* 2016). Contrasting with traditional GDP statistics based on administrative units, spatialized GDP data can delineate distinct economic patterns within administrative units and also support spatial analysis and correlation with other geographical data, such as natural resource availability and disaster-related information (Henderson *et al.* 2011; Elvidge *et al.* 2009).

Remote sensing NTL data are collected at night, minimizing common interferences. These data offer an effective reflection of human activities and serve multiple commercial purposes (Townsend and Bruce 2010; He *et al.* 2012; Levin and Duke 2012; Zhao *et al.* 2012; Bennett and Smith 2017; Wang *et al.* 2018; Xu *et al.* 2018; Li *et al.* 2019). Numerous studies have confirmed the relationship between economic activities and NTL, indicating the potential for spatializing social–economic data using NTL information (Li *et al.* 2017; Nataliya and Portnov 2014).

In recent years, the use of the Defense Meteorological Satellite Program Operational Linescan System (DMSP/OLS) has seen a growing application in the context of GDP growth and spatialization. This is primarily due to its capability to detect urban illumination, including even smaller, low-intensity sources, dating back to 1990. For instance, Elvidge *et al.* (1997) developed a quantitative degradation model based on GDP and night-time illumination data for 21 countries. Their findings revealed a strong association, with a coefficient of determination (R^2) of 0.97, signifying a robust link between NTL data and social and economic activities. Additionally, Sutton and Costanza (2002) pioneered the creation of the first 1-km global economic activity map using a degradation model that incorporated NTL and land cover data. They used this model to assess global economic activity.

Doll *et al.* (2006) went on to construct local maps of economic activity by examining the relationship between GDP and DMSP/OLS night-light data. In a similar vein, Ghosh *et al.* (2009) developed a regression model to explore the spatial patterns of NTL data and local economic indicators in the United States and Mexico. Their analysis, comparing projected state revenue with official financial data, indicated that the informal Mexican economy and remittance inflows held a greater influence than the official budget.

Furthermore, Chen *et al.* (2016) introduced a "dynamic regionalized technique," in which degradation models were individually constructed for subregions, resulting in a representation of China's mainland coastal GDP by integrating DMSP/OLS night-light and land use data. The introduction of National Polar-orbiting Partnership (NPP)/Visible Infrared Imaging Radiometer Suite (VIIRS) data has significantly improved both the precision and spatial resolution of experiments, overcoming the primary shortcomings of DMSP/OLS data, including saturation, blooming, and lack of onboard calibration (Shi *et al.* 2014; Chen *et al.* 2017). Chen *et al.* (2003) evaluated the potential of NPP/VIIRS data in economic modeling across 393 regions and 31 provinces in China. Their results indicated that NPP/VIIRS data outperformed DMSP/OLS data in predicting GDP and displayed a higher potential for local economic modeling. Additionally, Yu *et al.* (2017) conducted a correlation study using NTL data and a composite deficiency index, showing that NPP/VIIRS data can efficiently assess deficits at the county level in China.

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Contributed by Tolga Bakirman, February 8, 2023 (sent for review October 25, 2023; reviewed by Saket Gowravaram, Wenguang Hou, Shiguo Jiang).

Photogrammetric Engineering & Remote Sensing
Vol. 90, No. 4, April 2024, pp. 233–240.
0099-1112/22/233–240

doi: 10.14358/PERS.23-00010R2

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Honesty, justice, and courtesy form a moral philosophy which associated with mutual interest among people should be the principles on which ethics are founded.

Each person who is engaged in the use development and improvement of the mapping sciences (Photogrammetry Remote Sensing Geographic Information Systems and related disciplines) should accept those principles as a set of dynamic guides for conduct and a way of life rather than merely for passive observance. It is an inherent obligation to apply oneself to one's profession with all diligence and in so doing to be guided by this Code of Ethics.

Accordingly, each person in the mapping sciences profession shall have full regard for achieving excellence in the practice of the profession and the essentiality of maintaining the highest standards of ethical conduct in responsibilities and work for an employer all clients colleagues and associates and society at large and shall…

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Monitoring Based on InSAR for the Xinmo Village Landslide in Western Sichuan, China

Zezhong Zheng, Shuang Yu, Chuhang Xie, Jiali Yang, Mingcang Zhu, and He Yong

Abstract

A devastating landslide incident occurred on 24 June 2017, causing huge losses for Xinmo Village in western Sichuan. In this paper, we used two interferometric synthetic aperture radar (InSAR) methods, permanent scatterer (PS)-InSAR and small baseline subset (SBAS)-InSAR, to analyze deformation signals in the area in the 2 years leading up to the landslide event using Sentinel-1A ascending data. Our experimental findings from PS-InSAR and SBAS-InSAR revealed that the deformation rates in the study region ranged between −50 to 20 mm/year and −30 to 10 mm/year, respectively. Furthermore, the deformation rates of the same points, as determined by these methods, exhibited a significant increase prior to the event. We also investigated the causal relationship between rainfall and landslide events, demonstrating that deformation rates correlate with changes in rainfall, albeit with a time lag. Therefore, using time-series InSAR for landslide monitoring in Xinmo Village is a viable approach.

Introduction

Landslides are regarded as one of the most perilous natural catastrophes, typically resulting in significant loss of life and property, especially in mountainous regions. The causes of landslides are predominantly associated with gravitational stresses, but they can also be triggered by various factors including rainfall, seismic activity, and human activities (Chen *et al.* 2018; Abraham *et al.* 2020; Guzzetti *et al.* 2020). China, with approximately 70% of its land area covered by hills or mountains, is particularly susceptible to landslides due to its intricate topographical features. This susceptibility is especially pronounced in southwestern regions like Guizhou and Sichuan (Nohani *et al.* 2019; Pham *et al.* 2019) .

Sichuan Province is located in the southwestern part of China. The western Sichuan plateau is situated in the eastern Tibetan region and is primarily influenced by two distinct tectonic stress fields: one oriented from north to south and the other from east to west. As a result, the western Sichuan plateau exhibits a complex structural environment, characterized by significant earthquake activity. Successively, earthquake belts, namely the Batang earthquake belt, the Litang earthquake belt, and the Kangding earthquake belt, are distributed in this region. These earthquake belts are in proximity to the Jinshajiang fault zone, the Garzê-Litang fault zone, and the Xianshuihe fault zone, respectively (Pan *et al.* 2004; Li *et al.* 2008; Zhao *et al.* 2018; Huang *et al.* 2019). Historical earthquake records and recent reports from earthquake monitoring networks indicate that earthquakes in the western Sichuan plateau predominantly occur at depths ranging from 5 to 25 km, within the upper and middle crust, which is characterized by relatively brittle geological conditions (Fan *et al.* 2017; Hong *et al.* 2018) .

Over the past few decades, a wide range of studies has been conducted to monitor surface deformation caused by landslides. However, most traditional geodetic methods, such as GPS or leveling, primarily rely on point measurements at the Earth's surface, limiting their ability to provide a comprehensive view of surface movement across an entire study area. In contrast, differential interferometric synthetic aperture radar (D-InSAR) techniques offer unique advantages for detailed monitoring of surface deformation induced by landslides. D-InSAR can achieve very high spatial resolution, down to several millimeters, and provide extensive spatial coverage (Ye *et al.* 2004; Wang *et al.* 2020) .

Among the D-InSAR surface deformation monitoring methods, time-series (TS)-InSAR techniques have proven to be valuable tools for regional surface deformation monitoring (Lauknes *et al.* 2011; Fan *et al.* 2015; Xu *et al.* 2022) . Numerous advanced TS-InSAR techniques have been developed, including permanent scatterer (PS)-InSAR (Foumelis *et al.* 2018; Yang *et al.* 2019), small baseline subset (SBAS)-InSAR (Tizzani *et al.* 2007; Cigna and Tapete 2021), SqueeSAR (Bischoff *et al.* 2020), temporarily coherent point (TCP)-InSAR (Crippa *et al.* 2021), ground-based (GB)-InSAR (Zhang *et al.* 2012; Tarchi *et al.* 2013), GEOS-ATSA (Luzi 2010; Du *et al.* 2018a, 2018b), and distributed scatterer (DS)-InSAR (Du *et al.* 2016; Li *et al.* 2021; Wang, Xu *et al.* 2021). These methods are designed to monitor long-term deformation with high precision, typically involving more than 10 data scenes. It is important to note that PS-InSAR and SBAS-InSAR are the two most widely adopted TS-InSAR approaches for measuring surface deformation (Zhou *et al.* 2017; Wang, Zhao *et al.* 2021; Liu *et al.* 2022).

Based on the above discussion, this paper uses two kinds of TS-InSAR techniques to carry out surface deformation monitoring research and combines other environmental data to analyze the causes of landslides. The remaining chapters of this thesis are arranged as follows: "Study Area and Data Sets" introduces the research area and data. "Methodology" describes the research scheme and related technical principles of this paper. "Results" shows and analyzes the landslide monitoring findings. "Cause Analysis of Landslides" displays the results of the experiments. Then, the conclusion summarizes the study's main points.

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Zezhong Zheng, Shuang Yu, Chuhang Xie and Jiali Yang contributed equally to this study and should be considered as co-first authors.

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Contributed by Prasad S. Thenkabail, September 27, 2023 (sent for review October 16, 2023; reviewed by Yong Wang, Itiya Aneece).

Photogrammetric Engineering & Remote Sensing
Vol. 90, No. 4, April 2024, pp. 243–249.
0099-1112/22/243–249

doi: 10.14358/PERS.23-00072R2

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Investigation of Underwater Photogrammetry Method with Cost-Effective Action Cameras and Comparative Analysis between Reconstructed 3D Point Clouds

Seda Nur Gamze Hamal and Ali Ulvi

Abstract
Currently, digital cameras and equipment used underwater are often inaccessible to the general public due to their professional-grade quality and high cost. Therefore alternative solutions have been sought that are both cost-effective and suitable for nonprofessional use. A review of the literature shows that researchers primarily use GoPro action cameras, while other action cameras with similar capabilities are rarely used.This study thus examines underwater photogrammetry methods using a widely recognized action camera as a reference and compares it with another camera of similar characteristics as a potential alternative. For a comprehensive temporal analysis in underwater studies, both cameras were used to capture photographic and video imagery, and the resulting 3D point clouds were compared. Comparison criteria included data collection and processing times, point cloud densities, cloud-to-cloud analysis, and assessments of surface density and roughness. Having analysed, the study concluded that the proposed alternative action camera can feasibly be used in underwater photogrammetry.

Introduction
About 70% of the Earth is covered by water. While researchers can easily conduct their research on the land, it is not the same underwater. The discovery of underwater life, archaeological remains, biological resources, and underwater ecosystems have been explored through long-term studies but have resulted in incomplete and insufficient information transfer (Pacheco-Ruiz *et al.* 2018). When the first underwater studies were analyzed, it was observed that documentation studies were pioneering (Van Damme 2015). In documentation studies, traditional measurement techniques such as the length and area of underwater remains were used for metric information. However, these traditional measurement techniques come with several limitations, leading to incomplete data transmission about the study area (Drap *et al.* 2013; Nocerino *et al.* 2021). Due to the drawbacks of traditional measurement techniques in underwater studies, attempts to obtain metric information from photographs have been tried underwater. With the advancement of camera technology, the technique of digital photogrammetry has been implemented in underwater studies, thus introducing underwater photogrammetry into the literature (Guo *et al.* 2016).

The use of high-resolution digital cameras underwater necessitates the production of special housings due to the challenging underwater environment (Menna *et al.* 2016; Nocerino *et al.* 2021). However, the high cost and limited accessibility of digital cameras and underwater equipment have spurred the development of alternative solutions that are accessible to a broader audience. Particularly, action cameras and their accessories, offering relatively high resolution, have been incorporated into underwater studies (Helmholz *et al.* 2016; Guo *et al.* 2016; Bernardina *et al.* 2017). Action cameras are a new series of cameras that have attracted interest for their capacity for underwater photogrammetry studies due to their low cost and the fact that they are supplied with a standard underwater housing rated up to 60 m. Furthermore, their shape and size make them more advantageous for stereo use (Schmidt and Rzhanov 2012), while their easier access makes them attractive to researchers in underwater studies. However, a review of the literature indicates that almost all researchers use GoPro action cameras, with very little usage of other similarly featured action cameras. Moreover, there is a notable scarcity of research regarding which action cameras are more suitable for underwater photogrammetry. Pacheco-Ruiz *et al.* (2018) investigated the applicability of underwater photogrammetry to enhance and enrich the documentation process in shallow waters. Given that their research was conducted in shallow water, they constructed a lightweight rig and designed it with five GoPro Hero 5 Black cameras arranged to ensure mutual visibility and overlapping fields of view among them. This arrangement facilitated the collection of high-resolution images for 3D modeling of underwater objects under challenging visibility conditions and supported the use of low-cost, nonmetric cameras in underwater photogrammetry for creating digital archives. Raoult *et al.* (2016) compared the underwater photogrammetry method with the snorkel survey method. They showed that both methods showed similar results and that the GoPro camera used in the study was relatively reliable. In addition, they concluded that the snorkel survey method is time-consuming and that the underwater photogrammetry method can be an alternative to low-cost action cameras. Ahmad *et al.* (2020) compared the commonly used the coral video transect (CVT) method, with underwater photogrammetry, using low-cost action cameras. They reported that the orthophoto images obtained through photogrammetry showed similarities with those from CVT and that the 3D models produced by photogrammetry provided high-accuracy results. Statistically, they concluded that the results were close to 2D images and that underwater photogrammetry could potentially replace the CVT method.

Thanks to developing technologies and increased access to equipment, amateur camera users can easily use photogrammetry techniques underwater. Although methods of acquiring information from

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Contributed by Tolga Bakirman, June 10, 2023 (sent for review December 11, 2023; reviewed by Ece Alkan, Fanar M. Abed, Rong Yonghuang).

Photogrammetric Engineering & Remote Sensing
Vol. 90, No. 4, April 2024, pp. 251–259.
0099-1112/22/251–259

doi: 10.14358/PERS.23-00042R2

photographs are alternatives to traditional measurement techniques, the challenges associated with time spent underwater remain. Due to human physiology, it is recommended that a diver should not make more than three dives per day on average due to the accumulation of nitrogen in the body depending on the depth and duration of the dive. Therefore, the time divers spend underwater is limited (Kahraman *et al.* 2012; Güneş and Aktaş 2019).

In underwater photogrammetry, photography can take days or weeks when the area is large. Different alternatives have been tried in the data collection method in underwater photogrammetry, especially in large areas. In his study, Yamafune (2016) argued that a diver recording video can cover four times the area in the same duration as another diver taking photographs. In this case, it has been supported by scientific studies that more areas can be measured in a shorter time with video recording (Yamafune 2016). Van Damme (2015) conducted a documentation study of a submerged area spread over an area of 15 × 8 m with depths ranging between 16 and 20 m. Due to the large size of such an area for underwater studies and the changing depth making photography difficult, he proposed the video recording method in the study. An action camera was preferred for its ease of use, and video recording was performed under low-visibility conditions. The collected data were processed, and it was conveyed at the end of the study that the historical sunken area can be used in documentation studies with video data collection methods (Van Damme 2015).

Following these experimental studies, photogrammetry studies with video recording methods have gained momentum to reduce the measurement time as much as possible. However, detailed studies on the resolution and accuracy of action cameras, which are also the subject of this study, are still insufficient. Vogler (2019) examined the usability, applicability, advantages, and disadvantages of photo and video capture in underwater photogrammetry for 3D modeling. It was determined that the 3D model obtained by the underwater photogrammetry method has a higher resolution than underwater videogrammetry. However, it was concluded that the underwater photogrammetry method is time-consuming when comparing data generation and processing times (Vogler 2019).

Although the literature predominantly features various versions of GoPro brand action cameras (GoPro Hero Black 3, 5, 7, etc.) for underwater photogrammetry, there is a notable scarcity in the evaluation of other action cameras with relatively similar features (Capra *et al.* 2015; Letessier *et al.* 2015; Van Damme 2015; Guo *et al.* 2016; Helmholz *et al.* 2016; Raoult *et al.* 2016; Bernardina *et al.* 2017; Neyer *et al.* 2019; Nocerino *et al.* 2021; Piscaer *et al.* 2022). Moreover, when examining the prices of GoPro cameras and housings, they range between $600 and $800 (citation), which poses a challenge for researchers in lower-income countries. To address this issue, efforts have been made to identify alternative cameras. Additionally, the inclusion of different cameras in the literature aims to bring a fresh perspective to underwater studies. In this study, the 3D point clouds obtained from the GoPro Hero Black 9 action camera were considered as a reference, and the performance of the comparatively more cost-effective SJCAM 4000 brand action camera in the underwater photogrammetry method was examined. For this purpose, a platform was designed to prevent the object placed underwater from being affected by wave-induced displacements, and the object was securely fixed to this platform. Furthermore, target markers used to align data from different cameras to the same reference frame were homogeneously distributed and fixed on the platform in the same manner. After the platform was placed in the underwater environment, photographs and videos were taken. Comparative analyses were performed between the point clouds obtained from the photogrammetric evaluation of the data collected by both data collection techniques in the same coordinate system.

Materials and Methods

Metric cameras are recommended for photogrammetric studies. The most crucial characteristic of metric cameras is the knowledge of their internal orientation elements and camera distortion errors, and their geometric adherence to the theory of central projection. Metric cameras are more complex to use than other photographic cameras and are relatively difficult to obtain.. Therefore, the easy accessibility and user-friendliness of nonmetric cameras have led to their trial and increasing adoption in photogrammetry studies (Helmholz *et al.* 2016; Menna *et al.* 2016). As a result of the positive results obtained from studies, nonmetric cameras such as action cameras have started to be used in underwater research. Another important reason for trying action cameras in this field is that cameras specially designed for underwater studies are disadvantageous in terms of cost and require professionalism. Therefore, this study analyzes the usability of easily available action cameras in underwater photogrammetric studies. In the test study, two action cameras with different resolutions were used to collect underwater photo and video data (Figure 1).

Figure 1. (a) GoPro Black Hero 9 and housing. (b) SJCAM SJ4000 and housing.

Data Acquisition

The test study was conducted in a underwater environment at a depth of approximately 1 m. Weather conditions during data collection were clear (swell < 0.5 m, wind < 5 knots), and the sky was cloudy. This provided homogeneous illumination at relatively shallow depths. However, environmental factors can cause difficulties when photogrammetric work is performed at shallow depths. These environmental factors are blurred image acquisition due to wave and operator motion and the problem that the object and control points cannot remain fixed. In order to prevent the difficulties that may occur in this direction, the object and coded target marks were fixed on a platform. Then, the coordinates of the coded target marks were measured with an electronic length meter and placed in the water.

The diver captured images using the oblique method in a circular trajectory (Figure 2). Initially, GoPro (1/2.3″ CMOS rolling shutter; 1.11-µm pixel spacing; 5568 × 4192 pixels captured image size; 2.5-mm nominal focal length) was used to capture images and then video images. Afterward, the images were captured with the SJCAM camera (1/1.0″ CMOS rolling shutter; 0.25-µm pixel spacing; 4000 × 3000 pixels captured image size; 2.8-mm nominal focal length), and then video images were captured.

For both cameras, the overlap ratios were manually adjusted during the photo and video capture phase, and the overlap ratios were high (approximately 80% forward and 70% to the side). At the same time, more photos were taken due to close-ups.

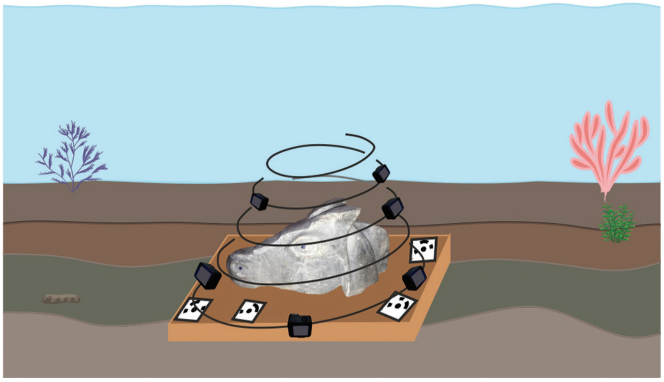

Figure 2. Designed platform and oblique photography for underwater photogrammetry.

Photogrammetric Process

Currently, several photogrammetric software suites allow the generation of 3D data of surfaces from photographs taken with cameras. Most are based on specialized algorithms such as structure from motion (SfM) (Pizarro *et al.* 2004; Ventura *et al.* 2021). SfM-based applications have increased significantly over the last decade due to the use of consumer-grade imaging platforms and sensors and the associated low cost of data acquisition, as well as increases in computing capacity and the availability of commercial and open-source software (Şasi and Yakar 2018).

SfM is a photogrammetric algorithm that automatically solves for scene geometry, camera positions, and orientation without requiring the predefinition of a target mesh with known 3D locations (Şasi and Yakar 2018). SfM, a measurement method based on computer visualization, has recently gained popularity and is not very expensive (Anderson *et al.* 2019; Jiang *et al.* 2020). For this reason, its use in scientific research has become very common. The SfM method involves taking overlapping photographs of the same area or object. Processing software then generates 3D data from the changing positions of the same points. SfM-based approaches can be applied to images captured from an aerial platform such as a handheld camera, airplane, balloon, kite, or unmanned aerial vehicle and to underwater imagery.

Many commercial photogrammetric software programs use the SfM algorithm. The most widely known of these, Agisoft Metashape, has been adopted by the scientific community for the photogrammetric process (Capra *et al.* 2015; Yamafune 2016). This software was used in this study, and the process was started simultaneously from two computers with the same specifications (Dual Intel Xeon Silver 4214 CPU / 64gb RAM / Quadro p4000 graphic card) for temporal comparison of the point clouds produced. Photo images were processed on one of the two computers, and video images were processed on the other. To start the process simultaneously, photo frames were first created from the video data. Since some of the photo frames were distorted due to motion, these photo frames were excluded from the photogrammetric process. After the preliminary preparations, the process started with the data collected from both methods simultaneously.

Image Processing and SfM Algorithm

Images were processed using Agisoft Metashape professional software. The process is largely automated, but the guidance provided by the software supplier, based on the effects of the underwater environment, the plan for photo and video capture, and sensor hardware, was mostly followed.

In photogrammetric softwares that use the SfM algorithm, a bundle block adjustment algorithm with ray bundles is used to minimize projection errors between the calculated point positions in the photographs. Software using this algorithm and methods first organizes the photographs to perform an initial balancing and creates a sparse point cloud. This involves working with algorithms that automatically position matching points between images (Jiang *et al.* 2020; Şasi 2020; Erdoğan *et al.* 2021; Yılmaz and Ulvi 2022).

Features detection and matching are applied as the first stage. In this stage, Agisoft Metashape starts the image alignment process by executing the scale-invariant feature transform (SIFT) algorithm to derive an initial point cloud consisting of matching key points in different images (Akçay *et al.* 2017; Yiğit and Uysal 2021a).

The SIFT algorithm refines the initial camera parameters using each image's corrected positions and orientations as a starting point. Through feature-matching algorithms such as the SIFT, a set of key points are identified in each image and stored in a database (Şasi and Yakar 2018). When the algorithm processes a new image, it recognizes its features and compares them with those already stored in the database using their identifiers. This results in finding common features between overlapping images, considered as matching points (i.e., connection points) (Kaya *et al.* 2023; Maraş and Nasery 2023). Furthermore, the SIFT algorithm can automatically detect and match key points between multiple images determined by local pixel variances, and outliers or false matches can be filtered and removed. The bundle adjustment system was performed iteratively to optimize the camera positions. In this step, a sparse point cloud can be created with the estimated 3D coordinates of key point matches (tie points) (Şenol and Orman 2022; Kaya *et al.* 2023; Yiğit *et al.* 2023). The limit of the number of points to be detected per image was set to 40,000 points for all data sets. Of these detected features, only those that matched in two or more images were reconstructed as 3D points. The limit of matching points was set to 0, and the alignment accuracy was set to "high" for all data sets. To make camera positions more precise, Ground Control Points (GCPs)were manually identified and marked on all available images to aid optimization before a multi-stereo algorithm generated a condensed point cloud containing the estimated 3D point locations. The next step was to densify the generated sparse point cloud to represent geometric detail accurately. This was accomplished by calculating binary depth maps for overlapping image pairs using the stereo matching algorithm, considering the relative camera parameters calculated in the previous step (Ulvi 2019; Ai *et al.* 2015; Şahin and Yılmaz 2021).

Another phase in SfM is the multi-view stereo stage. This phase involves creating a dense point cloud by densifying the sparse point cloud generated for accurate geometric detail representation. The algorithm used in this stage is the dense multi-view stereo (Kabadayı and Uysal 2019; Yiğit and Uysal 2021b). In this dense point cloud generation process, the solid model and the point cloud are generated by estimating the pixels that need to be mapped to each other and their virtual 3D positions. Camera positions derived from the bundle adjustment procedure are considered as input here. For the multi-view stereo algorithm, the clustering views separated the overlapping photos into manageable-sized subsets. The 3D point data were reconstructed independently from these separate subsets, and point densification was performed by the patch-based multi-view stereo algorithm (Ai *et al.* 2015). In this step, binary depth maps were calculated for overlapping image pairs using the stereo matching algorithm, considering the relative camera parameters calculated in the previous step. The binary depth maps were combined into partial dense clouds to form the final dense cloud. The quality of depth map generation was set to "high" with a mild filtering mode, which resulted in the removal of outliers (unwanted features) that were reconstructed due to image noise and poorly focused images, resulting in clear and reliable 3D data.

Analysis

This study examined the performance of low-cost cameras, considered an alternative to the cameras accepted in the literature underwater. For this purpose, data were collected underwater, and 3D data of all data sets were obtained due to the photogrammetric process. Various analyses were conducted on the obtained data. First, a temporal comparison of the data collection and data processing steps of the reference and comparison data sets was made. Here, the aim of obtaining optimum results in the shortest time spent underwater is presented, and the implications are discussed. Additionally, due to the importance of reaching quick results in a project, a temporal comparison of the data in terms of data processing was made. Lastly, comparisons and detailed analyses were conducted to evaluate the quality of the produced products.

For the analysis of the quality and suitability of the generated data, CloudCompare software was chosen. CloudCompare is open-source software that can produce deviation analysis from a 3D point cloud (Yamafune 2016). Since the generated data were in the same coordinate system, they were analyzed and compared separately.

In CloudCompare software, cloud to cloud (C2C), surface density, and roughness analyses were used. The C2C algorithm is the simplest and fastest 3D point cloud comparison algorithm for point clouds. Developed by Girardeau-Montaut *et al.* (2005), the algorithm is based on determining the distance of any point in the first point cloud to the nearest point in the second point cloud, without the need for any grid model or mesh model processing.

The C2C analysis works with the methodology of calculating the nearest neighbor distance of each point between the reference point cloud and the compared point cloud using the Hausdorff distance structure (Equation 1). The nearest neighbor distance principle is used to calculate the distances between two points, where for each point in the compared point cloud, the closest point in the reference cloud is searched, and the Euclidean distance is calculated.

$$d(p, s') = \min_{p' \in S'} p - p'_2 \quad (1)$$

Surface density analysis is estimated by counting the number of neighbors N for each point (within a sphere of radius R). The surface density used for this evaluation is the number of neighborhoods divided by the neighborhood surface. The software estimates the surface density for all points of the point cloud and then calculates the average value for an area of 1 m^2 proportionally. Surface density is considered a positive metric because it describes the number of points on a surface that is potentially generated, excluding noise present as points outside that surface. This is why the surface density metric is used instead of the volume density metric. The surface density tool of the CloudCompare software was used to find the surface density of the model (Weißmann *et al.* 2022).

The roughness tool of CloudCompare software was used to calculate the roughness. A value of 0.025 m was chosen as the dimension with radius R. Therefore, the lower the value, the less rough the dense point cloud is. The value used for our comparisons is the roughness average for all points in the dense point cloud (Weißmann *et al.* 2022).

Results

Data Acquisition and Data Processing Times

In this study, the determination of the test area, the preparation of the designed platform (placement of the test object and target markers on the platform), the measurement of the platform, and its placement underwater were not included in the temporal comparison as they are common to the whole process. Therefore, the focus of the study, namely the comparison of the data collection and photogrammetric data processing times between the reference camera (GoPro) and the comparatively less used SJCAM camera, was evaluated. During the data collection process, the GoPro camera took about 2 hours to capture photos and videos, while the SJCAM camera took about 2.5 hours. This difference is attributed to the automatic photo capture feature of the GoPro camera, which saved about half an hour. Since the photogrammetric process of the data obtained from both cameras was performed on Workstation computers with the same features (see "Photogrammetric Process" for detailed information), negative time delays due to hardware were ignored. In addition, to minimize hardware delays, the photographic data were processed on the same computer for both cameras, and the video data were processed on another computer.

In data processing, it was concluded that the data obtained from the reference camera required a long time and used more memory to generate photogrammetric outputs compared to the data obtained from the SJCAM camera (Figure 3). The fact that the raw images of the GoPro camera used as a reference are larger means larger file size and more information. For example, the average size of a GoPro image is 8.2 MB, while the SJCAM image is about 2.7 MB. This significant difference is due to the higher image resolution of GoPro images than SJCAM images. Figure 3 presents the processing time for the entire photogrammetric workflow as a bar graph for easier visualization and interpretation. In this way, processing steps and processing times can be easily compared with each other. For example, creating a mesh model, a polygonal network, and a dense cloud are the most time-consuming and memory-consuming steps across all data sets. As we predicted as authors before starting the process, the reference data, GoPro photo and video data, was the data set that took the most time to process.

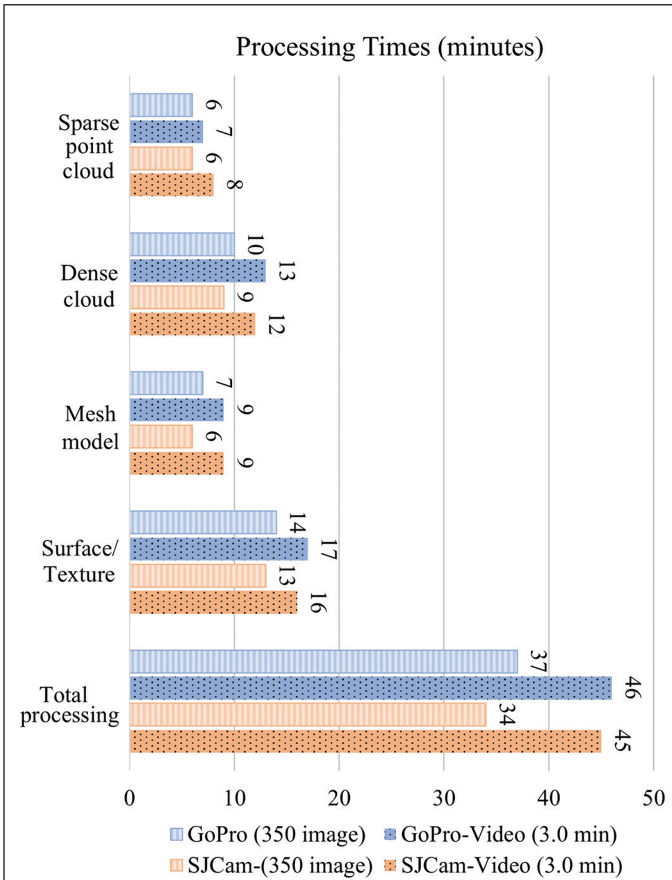

Figure 3. The bar graph displays the processing times for each step in photogrammetric software.

As a result of creating photo frames from video data for both cameras, more data was obtained than photo data. In fact, with more photo data, the photogrammetric process is expected to be longer. The processing time for products derived from GoPro photographs was approximately 37 minutes, while the data processing time from video data was about 46 minutes. Similarly, for SJCAM, the processing time for products obtained from photographs was approximately 34 minutes, while the data processing time from video was about 45 minutes. Thus, there was no significant difference in the processing of the data obtained from both cameras. However, the processing of the products obtained from the video data took more time than the processing of the products obtained from the images (Figure 3).

Comparison of Point Density

In the comparison of point densities, the number of dense points generated from the photo and video data obtained from the GoPro camera were approximately ~2.8 million and ~3.8 million, respectively. For the SJCAM camera, the number of dense points generated from the photo and video data were approximately ~2.1 million and ~3.5 million, respectively. The reason for the higher number of dense points generated from the video data for both cameras is attributed to the excess of outlier points considered as noise (Figure 4).

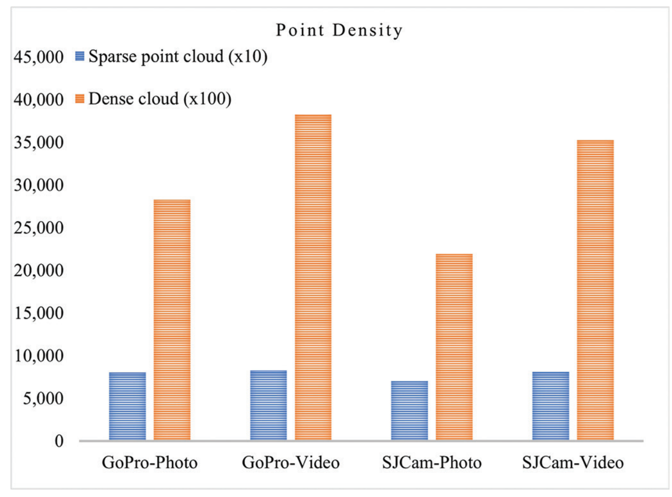

Figure 4. The bar graph displays sparse and dense point clouds from the GoPro and SJCAM data sets, which have been normalized to highlight the differences between them.

C2C, Surface Density, and Roughness Analysis

In order to test the compatibility of the underwater photogrammetry method with action cameras, firstly, a C2C distance analysis between point clouds was made. For this purpose, C2C tool was used in CloudCompare open source software (CloudCompare 2023). The C2C tool uses the nearest neighbor algorithm to calculate the Euclidean distance between each point of the compared cloud and the nearest point of the reference cloud (Dabove *et al.* 2019). Since target marks were used for referencing in the study, scaling in any reference system was not required. Figures 5 and 6 illustrate some of the key results from this procedure by displaying histograms, statistical distributions, and a color scale directly on point clouds. The high accuracy of the models, as well as the metric accuracy, is verified by calculating the differences from the data generated from both cameras. The C2C analysis between GoPro (photos) and SJCAM (photos) resulted in a maximum error of 0.03 cm, an average distance of 0.008 m, and a standard deviation of 0.005 m, while between GoPro (video) and SJCAM (video), the maximum error was 0.04 cm, average distance was 0.008 m, and standard deviation was 0.006 m.

The surface density of point clouds was calculated to analyze point cloud properties. This step was performed using the surface density analysis tool in CloudCompare software (CloudCompare 2023). The point density of point clouds is an important influence factor for the reconstruction of surfaces, as they represent the surface as points, and the reconstruction is calculated based on these points (Weißmann *et al.* 2022). Figure 7 shows the surface density and the distribution of spots on the surface. The blue color represents the lowest dot density, and the red color represents the maximum dot density. The green and yellow colors show the uniform distribution of the dots. The search radius values of 0.025 m were chosen to calculate the surface density. Considering the surface density of digital outputs created with GoPro photos, GoPro video, SJCAM photos, and SJCAM video data sets with a radius of 0.025 m ($r = 0.025$), the mean and standard deviation values in the analysis results are given in Table 1.

When examining Table 1 and Figure 7, it is observed that the dense point cloud obtained from GoPro images is homogeneously distributed and has an average surface density. It is seen that the front and back surfaces of the dense point cloud obtained with the GoPro video have an increased surface density. In contrast, the point cloud in the remaining parts has a value of approximately average surface density. The dense point cloud obtained with the SJCAM image has the least surface density. The lateral surfaces of this dense point cloud have been shown to have a decreasing surface density compared to the rest of the exhibited point clouds. While the point cloud on the top of the object is at an average surface density, the lateral surfaces are below the average. It was observed that the lateral surfaces of the dense point cloud obtained by the SJCAM video remained below the average surface density in the detail part. However, it was homogeneously distributed in the remaining parts.

A roughness analysis was performed to understand the average noise level and the roughness of points compared to normal surfaces in the 3D point cloud of the test object. This step was performed using the roughness analysis tool in CloudCompare software. This tool calculates the roughness level in the x, y, and z directions based on a local neighborhood radius. The roughness values of a point in the analysis section (0.025 m) are equal to the distance between them, and the most suitable plan is calculated over its nearest neighbors. The roughness of the products obtained with GoPro photos, GoPro video, SJCAM photos, and SJCAM video is between 0.0 and 0.14 cm, 0.0 and 0.16 cm, 0.0 and 0.21 cm, and 0.0 and 0.23 cm, respectively; the mean error is 0.019, 0.021, 0.024, 0.026 cm, respectively; and the standard deviations are 0.017, 0.19, 0.022, and 0.024 cm, respectively. Approximately 97% of the points record roughness values below 10 mm, while only 0.25% exceed 15 mm. The highest roughness values were obtained at the object's base and considered minor imperfections. Generally, the analyzed point cloud has very small deviations in roughness analysis (Figure 8).

Conclusions

The primary objective of this study was to explore action cameras as potential alternatives to the digital cameras currently used in underwater studies and to examine whether a camera other than the widely used

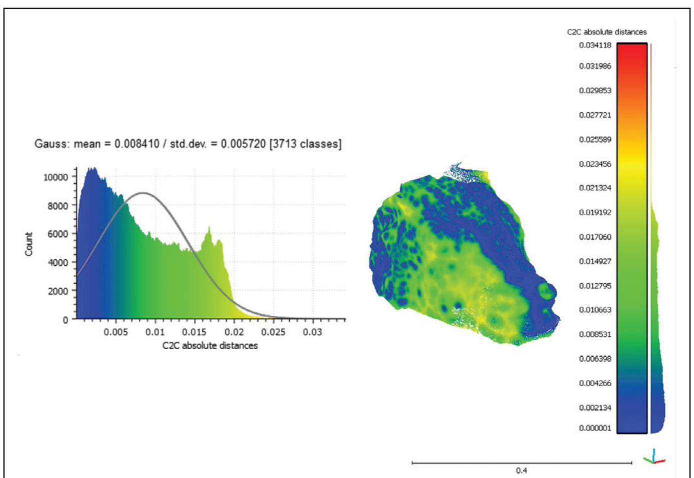

Figure 5. Cloud to cloud (C2C) analysis of digital outputs of GoPro and SJCAM image data sets.

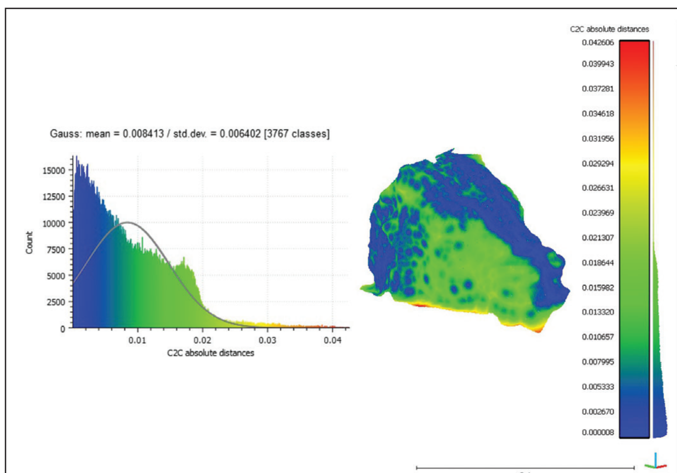

Figure 6. C2C analysis of digital outputs of GoPro and SJCAM video data sets.

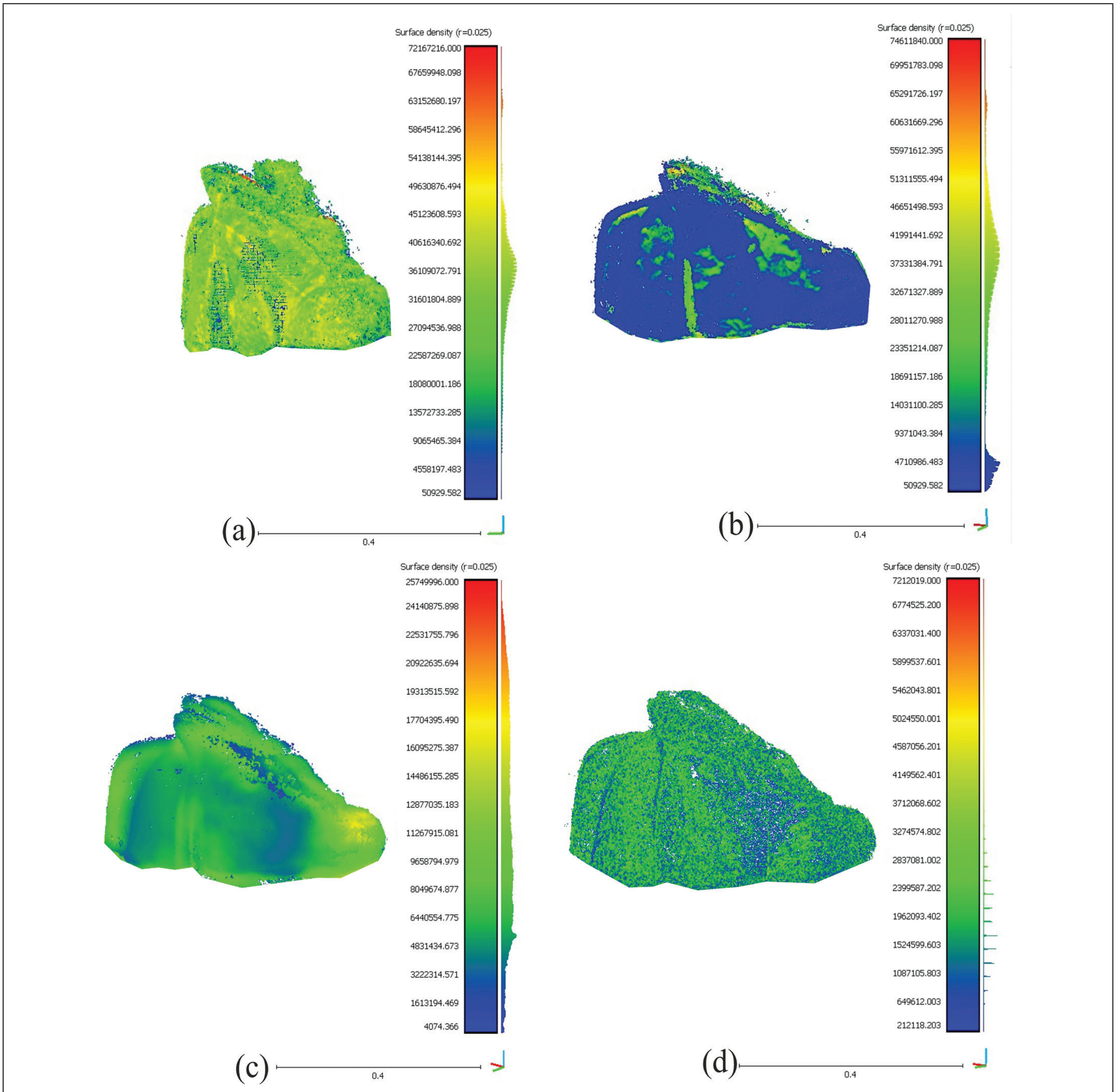

Figure 7. Distribution of surface densities at each point in the point cloud. (a) GoPro image. (b) SJCAM image. (c) GoPro video. (d) SJCAM video.

Table 1. Mean and standard deviation values of surface densities at each point in the point cloud created with each data set.

	Surface Density Analysis		
Data Set	Count	Mean ($\times 10^5$)	Standard Deviation ($\times 10^5$)
GoPro photo	2,829,945	6.91	2.74
GoPro video	3,830,149	6.24	1.47
SJCAM photo	2,194,747	6.34	1.89
SJCAM video	3,526,624	5.98	1.54

GoPro could also be a viable alternative, thereby offering a different perspective to the literature in this direction. This is because digital cameras and equipment used underwater are typically accessible only to professionals due to their high cost and hence not readily available to everyone. Moreover, a review of the literature reveals that almost all researchers have used versions of GoPro action cameras, with very little usage of other action cameras that have nearly identical features. There is also a notable scarcity of research on which action cameras might be more suitable.

In recent years, there has an increasing demand for innovative methods focused on various multidisciplinary studies to explore, examine, and accurately measure the underwater environment in an easy and efficient manner. Foremost among these methods is underwater photogrammetry. Although there is no definite threshold for when the

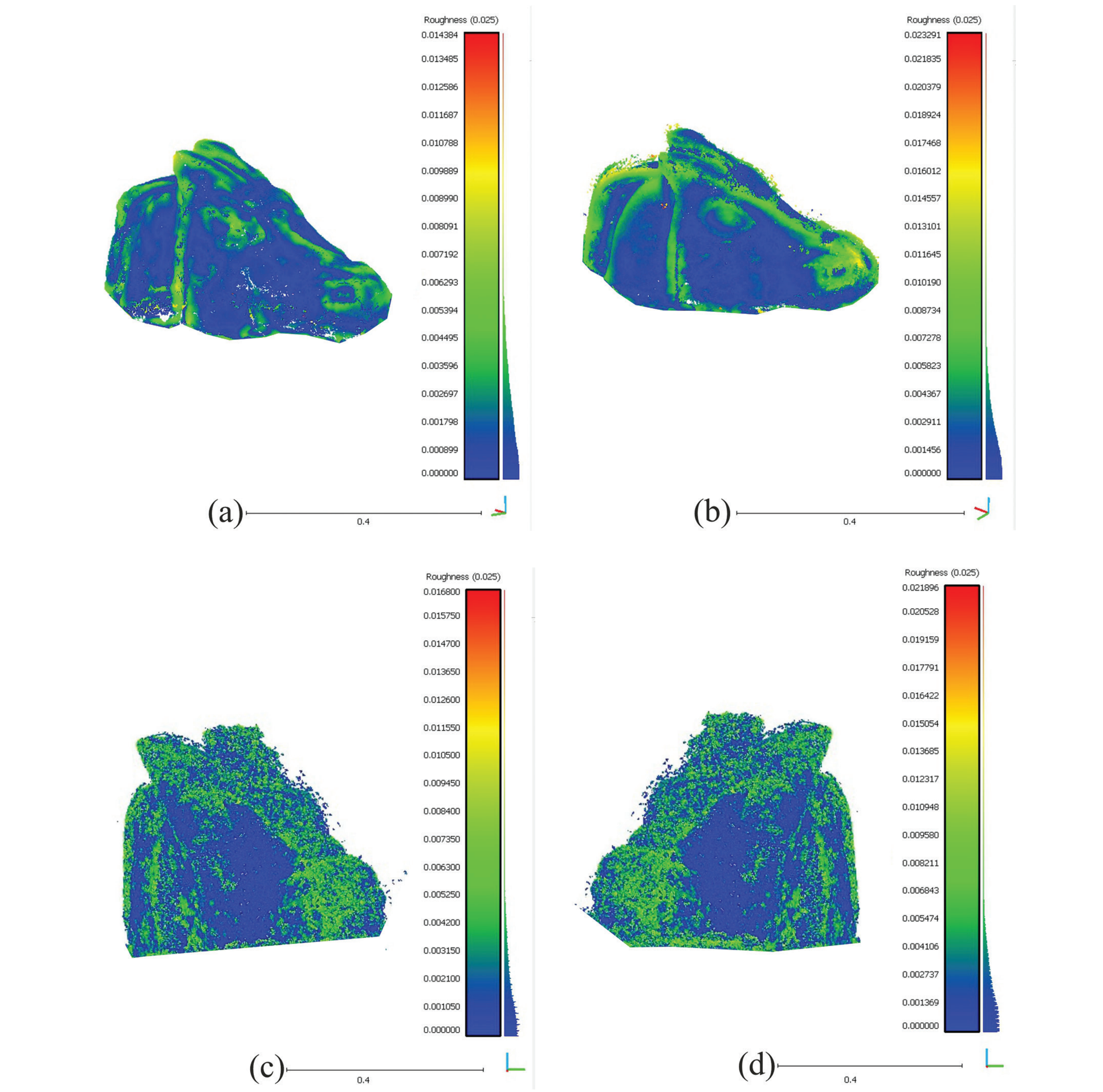

Figure 8. Distribution of roughness analysis at each point in the point cloud. (a) GoPro image. (b) SJCAM image. (c) GoPro video. (d) SJCAM video.

use of underwater photogrammetry is appropriate, the best photogrammetric scenarios can often be produced especially in conditions of high-water clarity, calm surface conditions, minimal wave action, and slightly cloudy days. While the photogrammetry method has its advantages, there is a limit to the minimum depth required for this method. The method does not work well in conditions with less than 0.5 m of water due to low overlap between photos and less distinctive features per photo. However, at this point, the advantage of the action camera is emphasized. In other words, the smaller size and easier use of action cameras compared with other professional cameras make them easier to use at shallow depths.

Among the advantages of the action camera in underwater photogrammetry studies are affordability and easy accessibility, ease of transportation, and easy storage underwater. An action camera may be preferable, especially in homogeneous environments (seagrass beds, dead coral/rubble habitats) or where it is only evaluated at large spatial scales, such as large community measurements (abundance, diversity). As reported by Raoult *et al.* (2016), this study also supports the successful application of photogrammetry methods with images taken from GoPro cameras in underwater studies. Ahmad *et al.* (2020) reported that the 3D model produced by the photogrammetry method gave high-accuracy results. The statistical comparison in the study concluded that the underwater photogrammetry method could potentially replace the reference method, with very little difference noted between the methods. Generally, in the literature, low-budget, easy-to-maneuver GoPro action cameras have been preferred for underwater photogrammetry studies (Costa 2022; Pacheco-Ruiz *et al.* 2018). Data collected with action cameras have been combined in a hybrid manner to produce photogrammetric digital products, but there has been little investigation into which action cameras are more suitable for underwater photogrammetry. The literature generally includes comparisons of action cameras with the same features as professional ones. Although the study of action cameras as an alternative to professional cameras has increased, the variety of action cameras used underwater in scientific studies has not increased much. Therefore, in our study, the use of alternative action cameras in underwater surveys has been examined. In this study, two action cameras were compared using both photo and video recordings.

Suitable conditions were chosen to collect data, and a depth of 1 m was preferred for the platform due to environmental factors, as the article compares the performance of the cameras. As expected, the study concluded that the photo data from the reference camera showed quite successful results. In addition, the camera suggested as an alternative also produced very close results. Moreover, as anticipated, the video recording during the underwater field phase was completed in a shorter time, but more time was spent in the data processing phase, including manual photo editing. Nevertheless, while creating frames from video footage, the alignment of the photos was facilitated due to a higher overlap ratio of consecutive images. However, it was observed that not all of the frames were suitable for photogrammetric processing, necessitating manual filtering. Also, the extracted frames have lower image resolution, resulting in a lack of color in the images.

When comparing the two cameras, the data collection process with the GoPro camera took more time than the SJCAM camera. This is primarily due to the GoPro camera's automatic photo capture feature. The processing time for products obtained from photos with GoPro took approximately 37 minutes, while data processing from video data took approximately 46 minutes. Likewise, the processing time of the products obtained from the photographs with SJCAM took approximately 34 minutes, while the data processing process from the video data took approximately 45 minutes. Therefore, there was no significant difference in the processing times of the data obtained from both cameras. However, the processing times of the products obtained from the video data took more time than the processing of the products obtained from the photograph (Figure 3). The primary reason for this can be attributed to the resolution of the images. However, since this study was conducted in a small test area, the differences are in the order of minutes. In larger study areas, the data collection and processing times can take hours or even days. Therefore, it is recommended to select the camera and choose between photo or video recording according to the size and purpose of the study.

In the comparison of point densities, it was found that the dense point cloud generated from video data for both cameras had a higher number of points in the same direction compared to the dense point clouds generated from photo data. This increase was attributed to the excess of outlier points considered as noise (Figure 4).

Following the statistical analyses, the initial C2C analysis was performed, and it was concluded that the SJCAM camera was similar to the digital products produced with the GoPro camera due to the differences in mm. However, since only the results of this analysis will represent the data number and data quality, surface density and roughness analyses were also performed. According to the surface density analysis, the distributions of the point clouds produced from both the reference camera and alternative camera were quite consistent. However, even though the numerical values of SJCAM data appeared close, they showed differences in distribution. Particularly on sharp surfaces, while appearing consistent, it did not achieve a homogeneous point density on surfaces with smoother transitions. Therefore, it is thought that there is a lack of data in the smooth transitions of the camera, which is considered an alternative. Similarly, the roughness analysis revealed results parallel to the surface density. However, it was concluded that the digital outputs generated from both video data sources were rougher compared to those generated from photo data.

In conclusion, SJCAM is a viable alternative to the commonly used GoPro cameras in the literature. While there is no discernible difference between the two in terms of temporal image processing, SJCAM's advantage in terms of data size makes a significant contribution to data storage. It has been demonstrated that SJCAM can be used for photogrammetric purposes, as evidenced by a statistical comparison of dense point cloud noise levels between video and images. The similarity between SJCAM and GoPro cameras, as measured by multiple metrics, is valuable for future studies. The aim is to test the cost-effective platform in deeper environments and under more challenging environmental conditions and to further develop it in the future. Additionally, it will be possible to compare whether the newly developed platform can achieve the same level of success as the current study in deeper waters. Furthermore, it was concluded that multiple measurements should be evaluated in varying underwater conditions, including different depths, seasons, and measurement times. Therefore, future evaluations with diverse data sets and larger areas under varying conditions may yield concrete results on the production of the best 3D point clouds in an underwater environment. This demonstrates the versatility of underwater photogrammetry in various fields. The research model presented confirms the potential use of underwater cameras in close-range photogrammetry. It represents a new starting point for further research in the field of underwater photogrammetry. Furthermore, point cloud models can be used as a tool for online 3D spatial analysis, virtual reality, and augmented reality models or WebGL models through various software programs.

Acknowledgments

This article was prepared from the thesis of Seda Nur Gamze HAMAL, a graduate student at Mersin University Institute of Science and Technology, Remote Sensing and Geographic Information Systems.

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